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Nakajiki et al.

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(45) **Date of Patent: Feb. 16, 2016**

(54) **IMAGE PICKUP ELEMENT, IMAGING APPARATUS, MANUFACTURING APPARATUS FOR IMAGE PICKUP ELEMENT, AND MANUFACTURING METHOD FOR IMAGE PICKUP ELEMENT**

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(30) **Foreign Application Priority Data**

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H01L 27/146 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 27/14643*** (2013.01); ***H01L 27/14623*** (2013.01); ***H01L 27/14627*** (2013.01); ***H01L 27/14685*** (2013.01); ***H01L 27/14689*** (2013.01)

(58) **Field of Classification Search**
CPC H01L 27/146–27/14893
See application file for complete search history.

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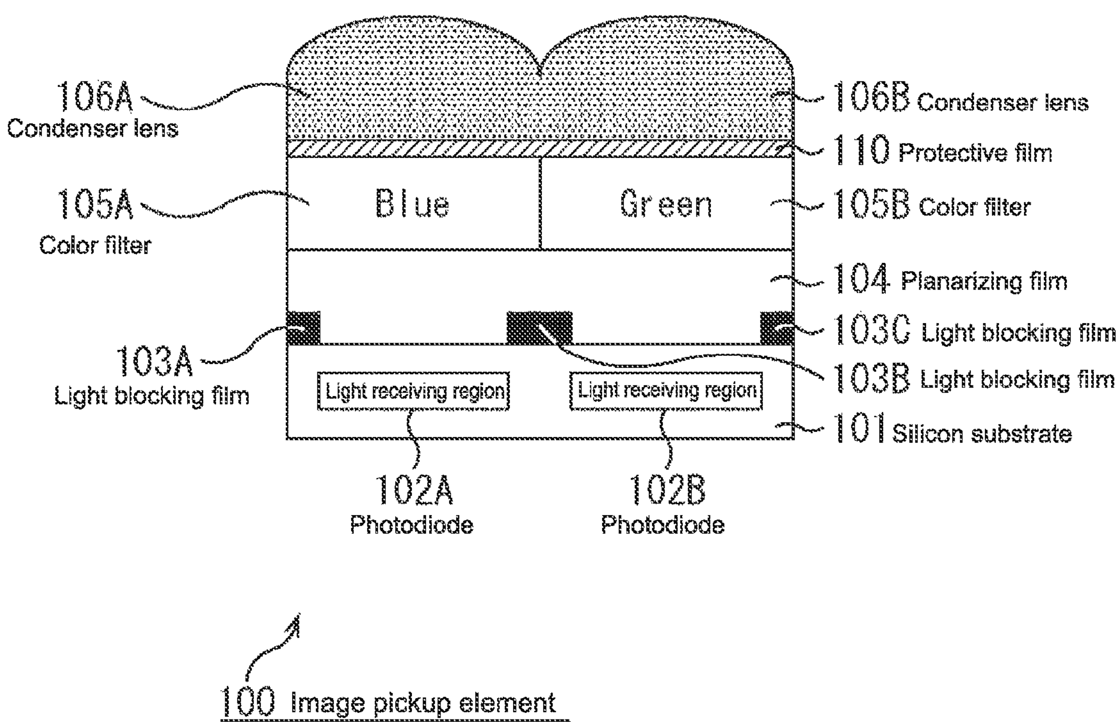
(57) **ABSTRACT**

Provided is an image pickup element, including: condenser lenses made of a resin containing fine metal particles; photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses; and a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate.

16 Claims, 14 Drawing Sheets



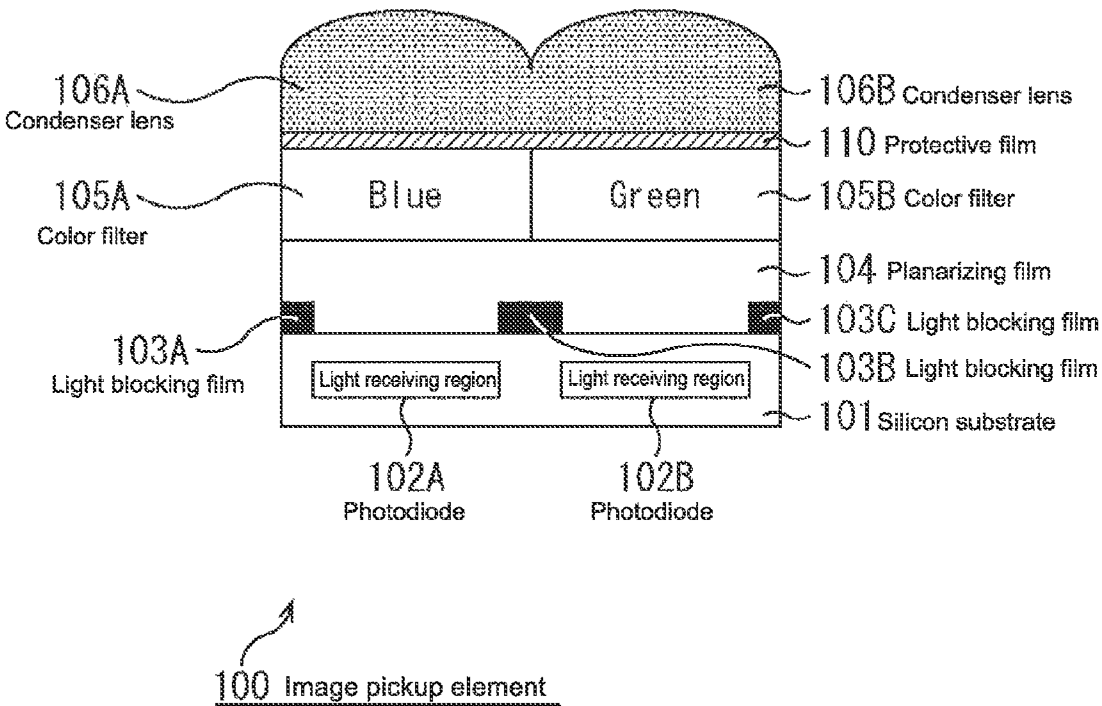

106A
Condenser lens
105A
Color filter
103A
Light blocking film
Blue
Green
Light receiving region
Light receiving region
106B Condenser lens
110 Protective film
105B Color filter
104 Planarizing film
103C Light blocking film
103B Light blocking film
101 Silicon substrate
102A
Photodiode
102B
Photodiode
100 Image pickup element

FIG.1

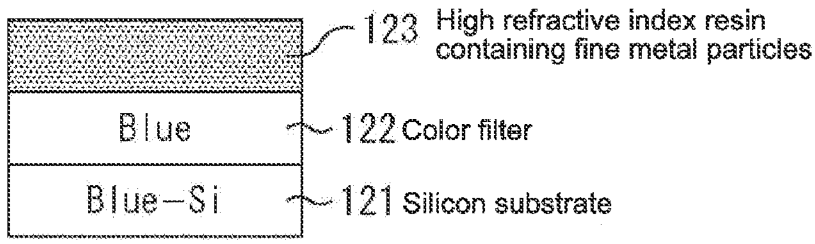

123 High refractive index resin containing fine metal particles
Blue
122 Color filter
Blue-Si
121 Silicon substrate

FIG.2A

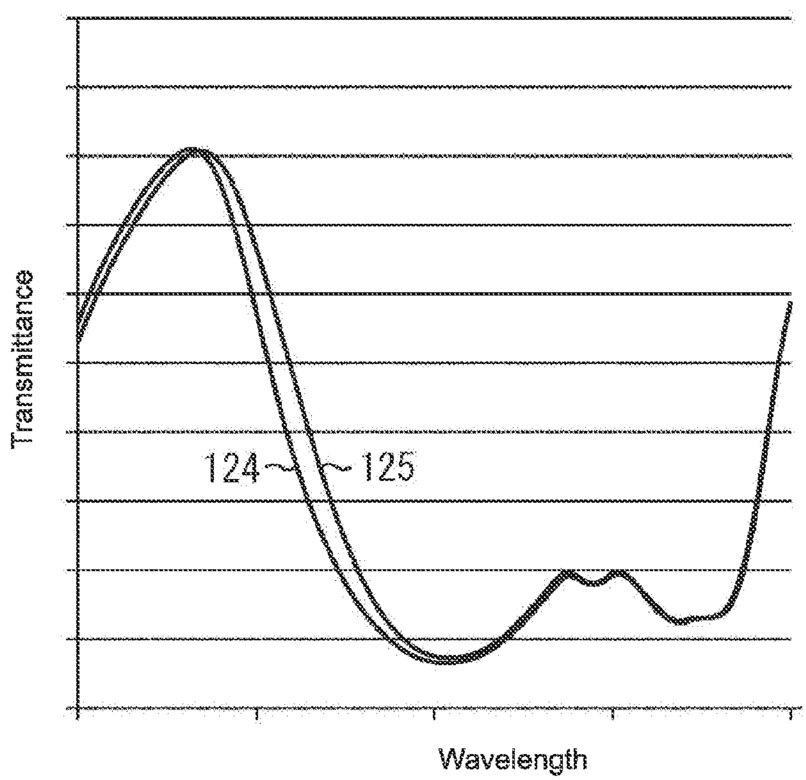

Transmittance
124
125
Wavelength

FIG.2B

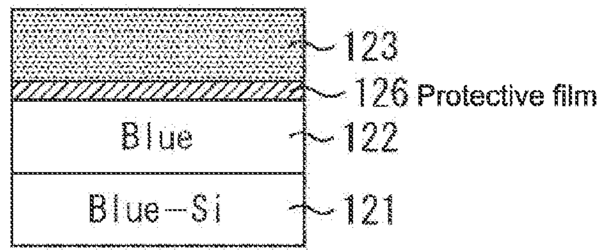


FIG.3A

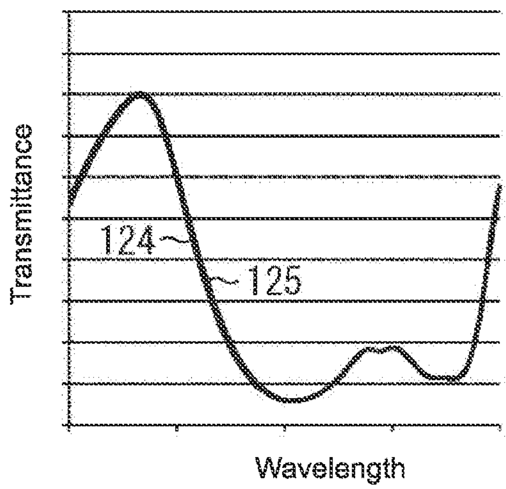


FIG.3B

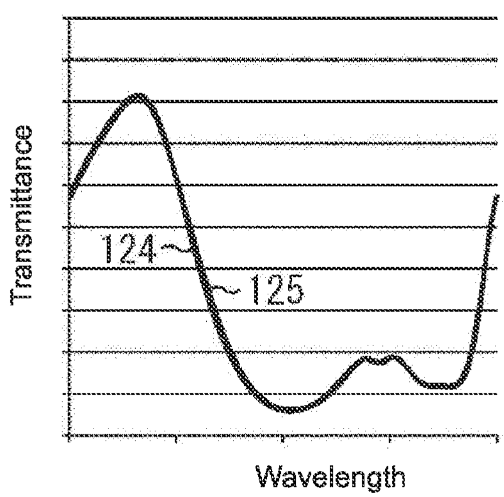


FIG.3C

FIG.4A

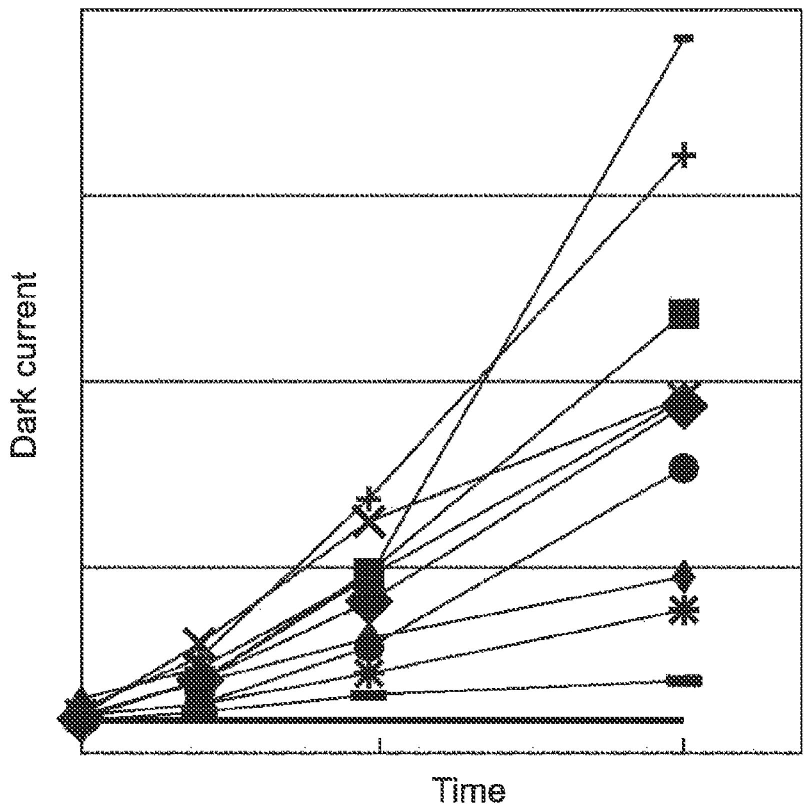


FIG.4B

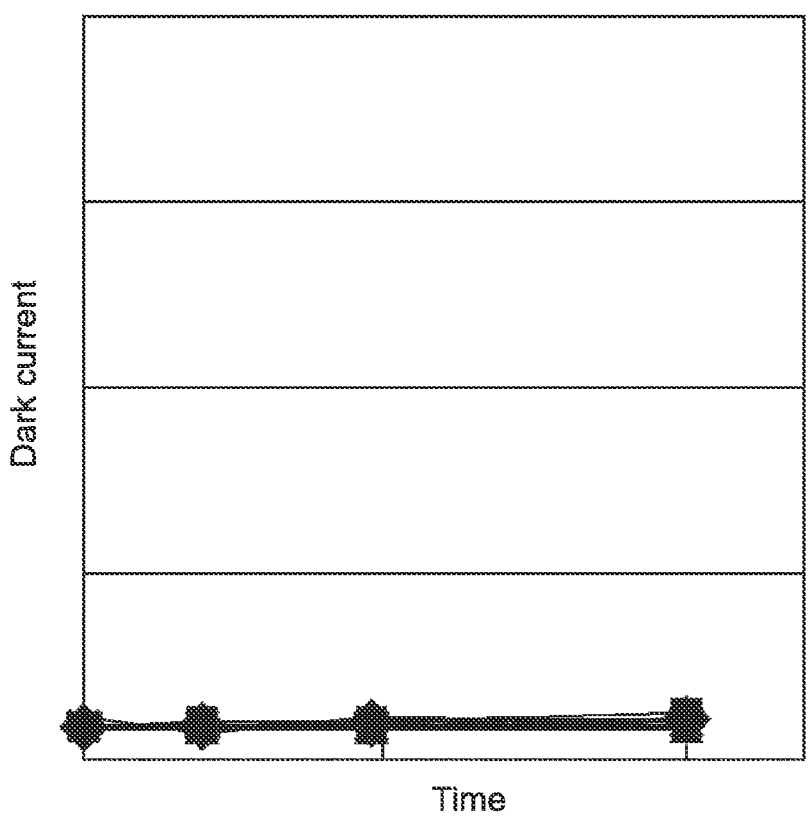


FIG.5A

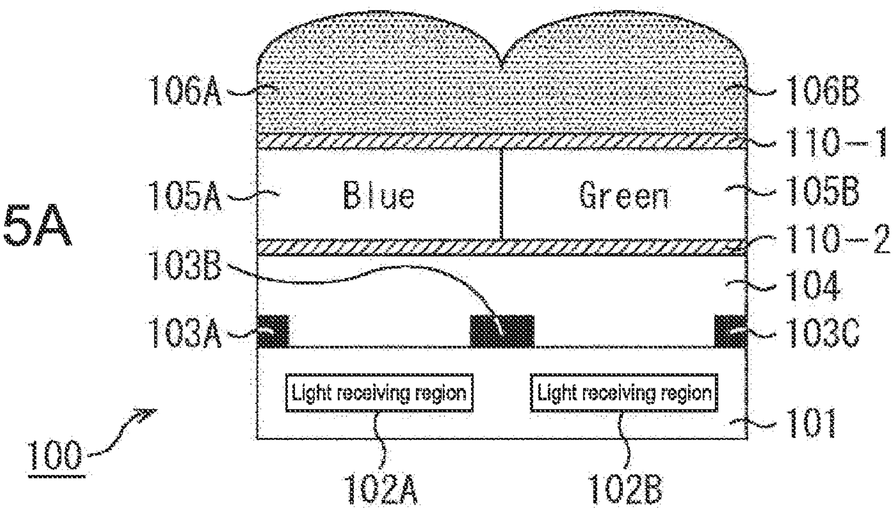


FIG.5B

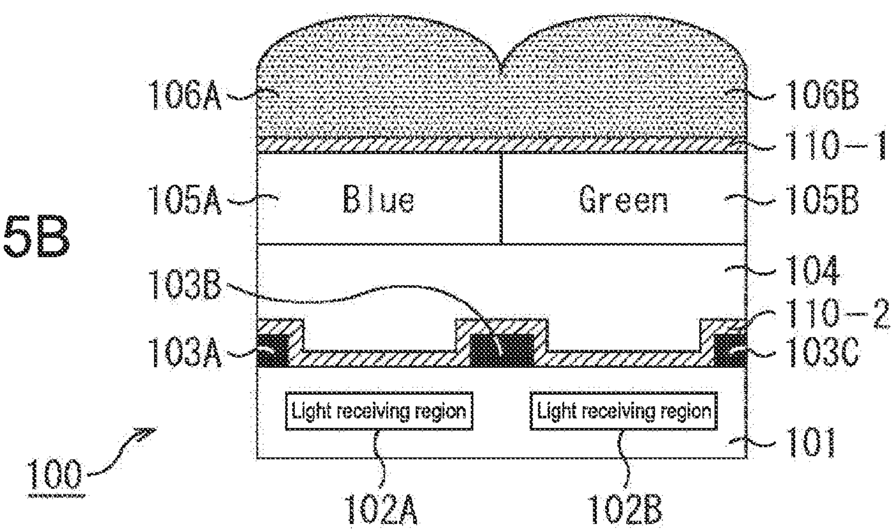


FIG.5C

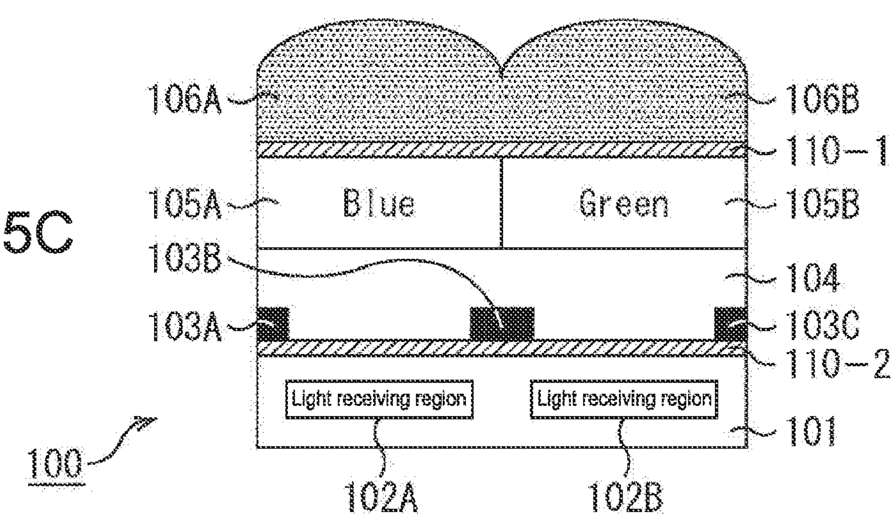


FIG.6A

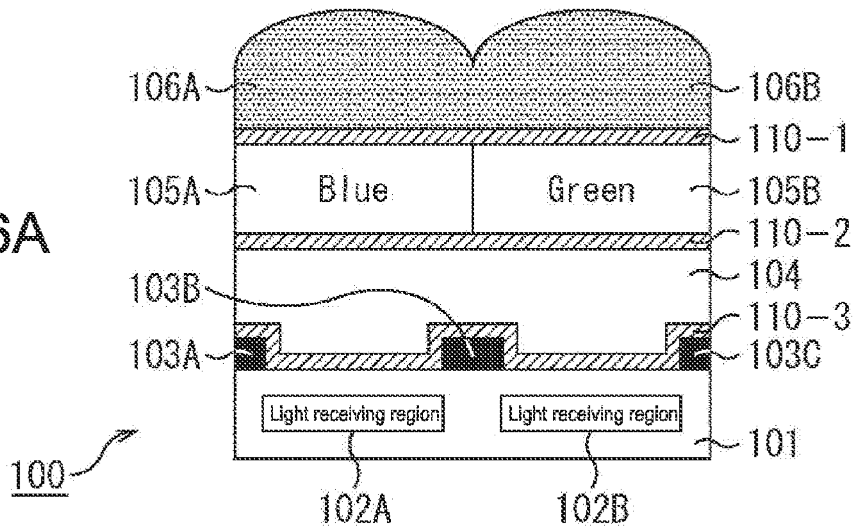

106A
106B
110-1
105A
Blue
Green
105B
110-2
104
103B
110-3
103A
103C
Light receiving region
Light receiving region
101
100
102A
102B

FIG.6B

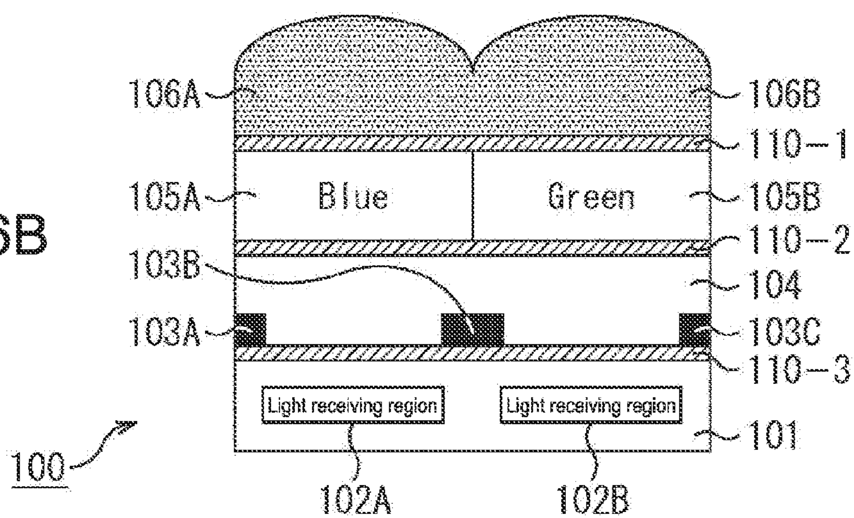

106A
106B
110-1
105A
Blue
Green
105B
110-2
103B
104
103A
103C
110-3
Light receiving region
Light receiving region
101
100
102A
102B

FIG.7A

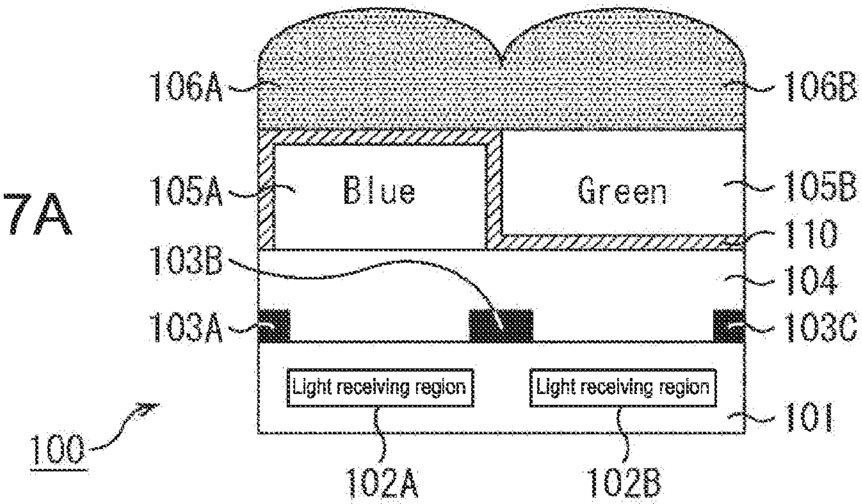


FIG.7B

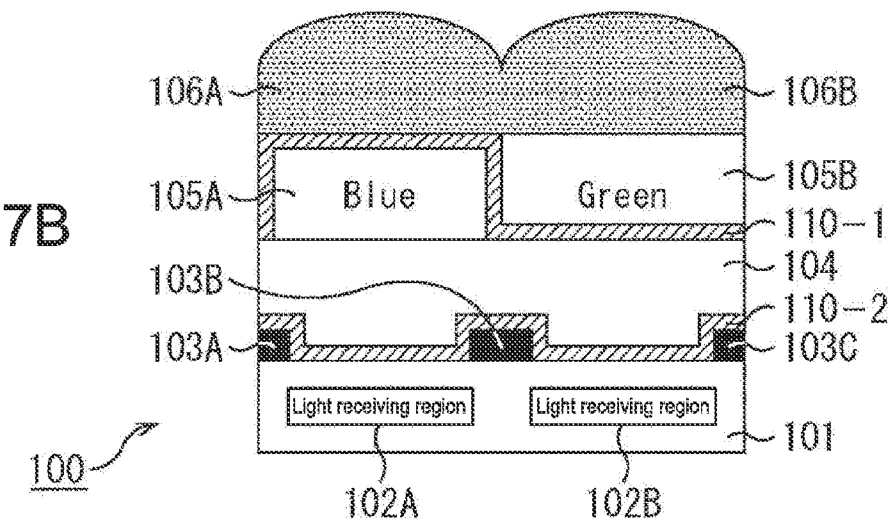


FIG.7C

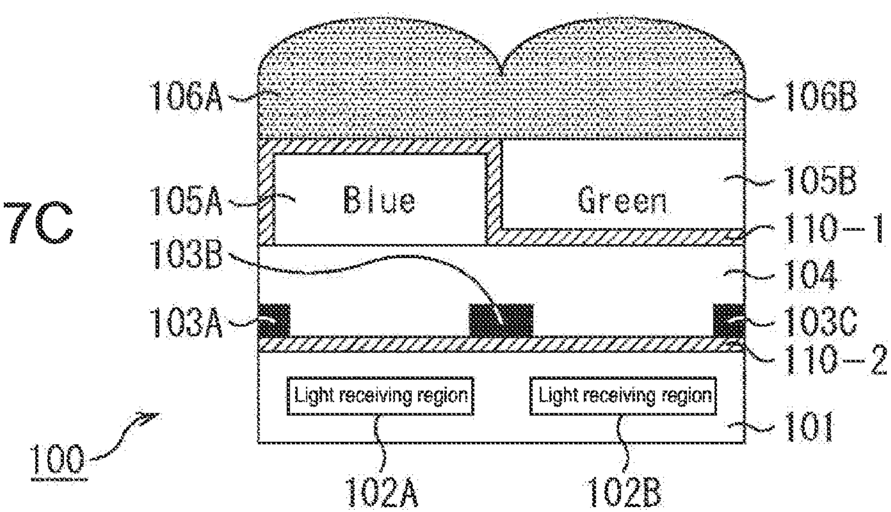


FIG.8A

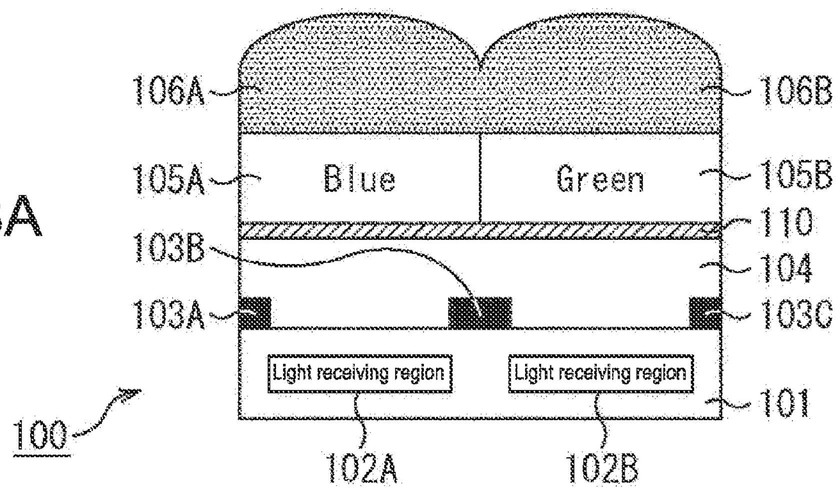


FIG.8B

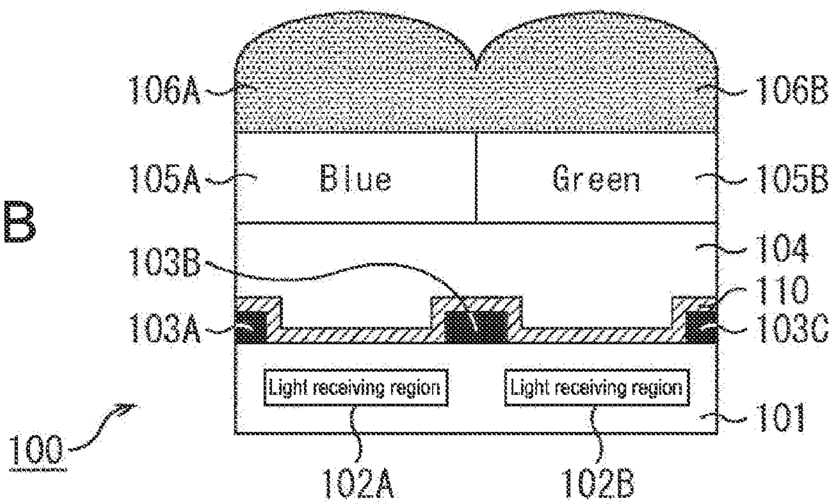


FIG.8C

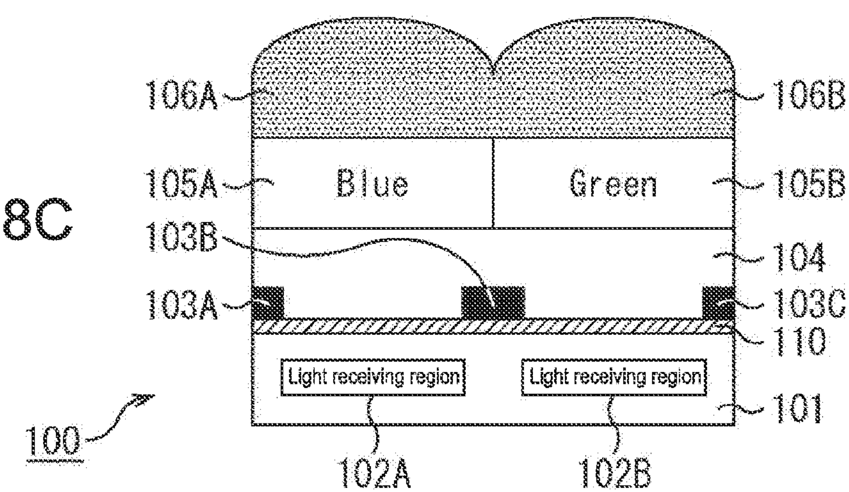


FIG.9A

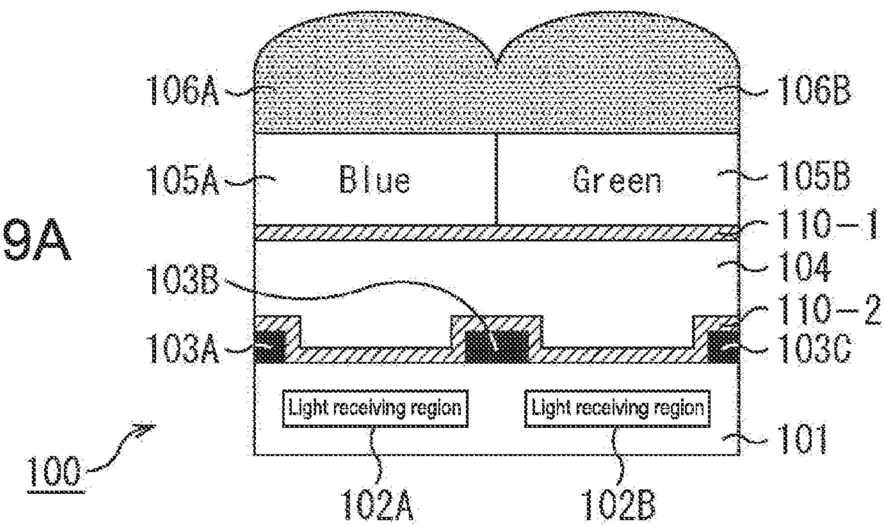
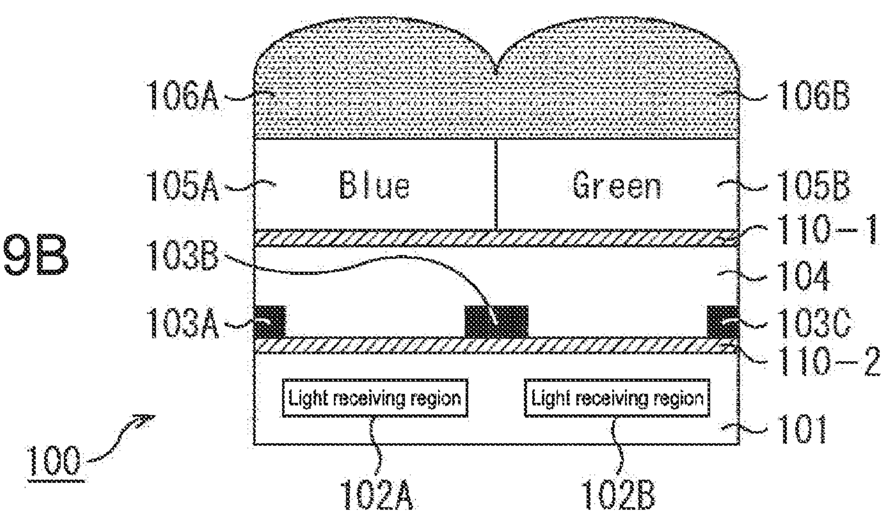
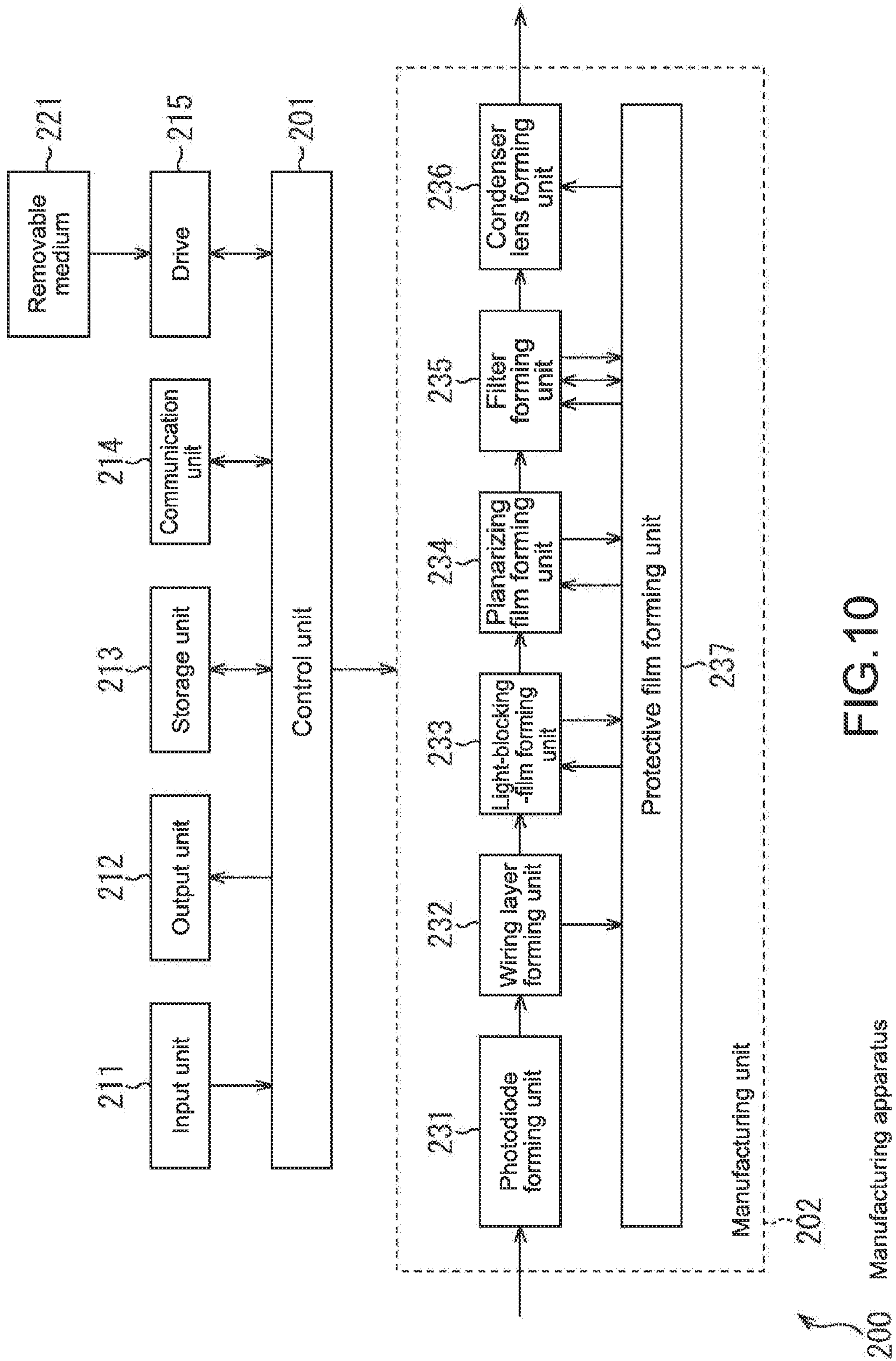

106A
106B
105A
Blue
Green
105B
110-1
104
103B
110-2
103A
103C
Light receiving region
Light receiving region
101
100
102A
102B

FIG.9B


106A
106B
105A
Blue
Green
105B
110-1
103B
104
103A
103C
110-2
Light receiving region
Light receiving region
101
100
102A
102B



200
Manufacturing apparatus
Removable medium
221
Drive
215
Communication unit
214
Storage unit
213
Output unit
212
Input unit
211
Control unit
201
Manufacturing unit
202
Photodiode forming unit
231
Wiring layer forming unit
232
Light-blocking-film forming unit
233
Planarizing film forming unit
234
Filter forming unit
235
Condenser lens forming unit
236
Protective film forming unit
237

FIG. 10

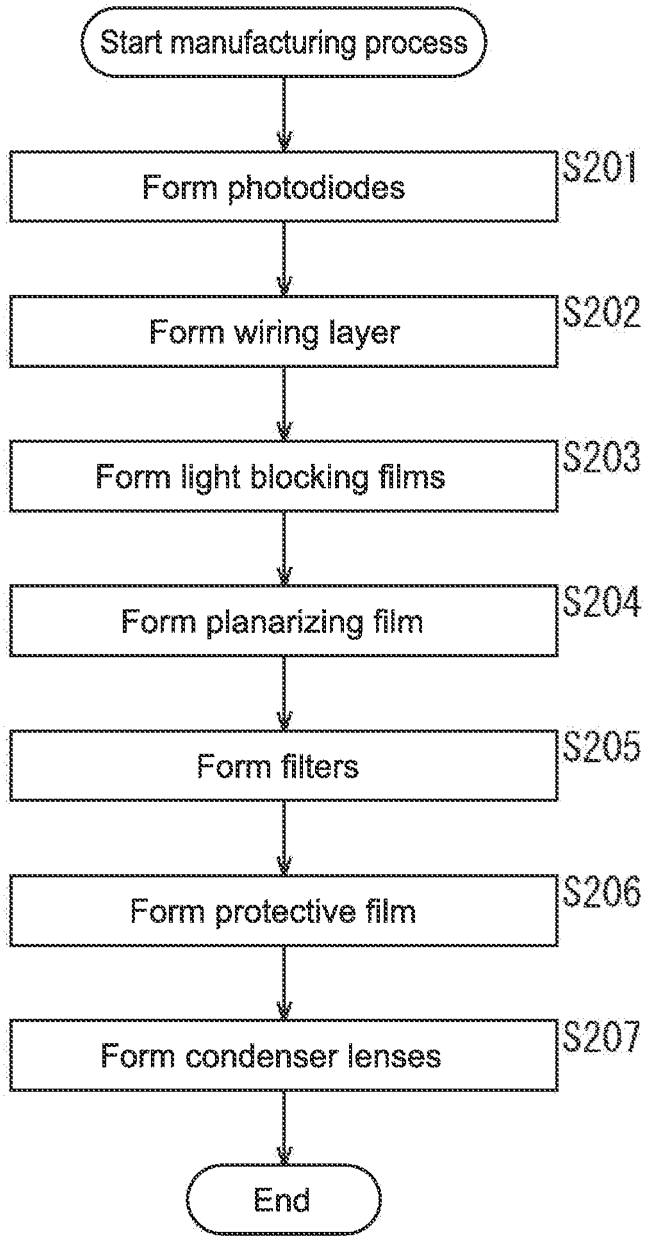

Start manufacturing process
Form photodiodes
S201
Form wiring layer
S202
Form light blocking films
S203
Form planarizing film
S204
Form filters
S205
Form protective film
S206
Form condenser lenses
S207
End

FIG.11

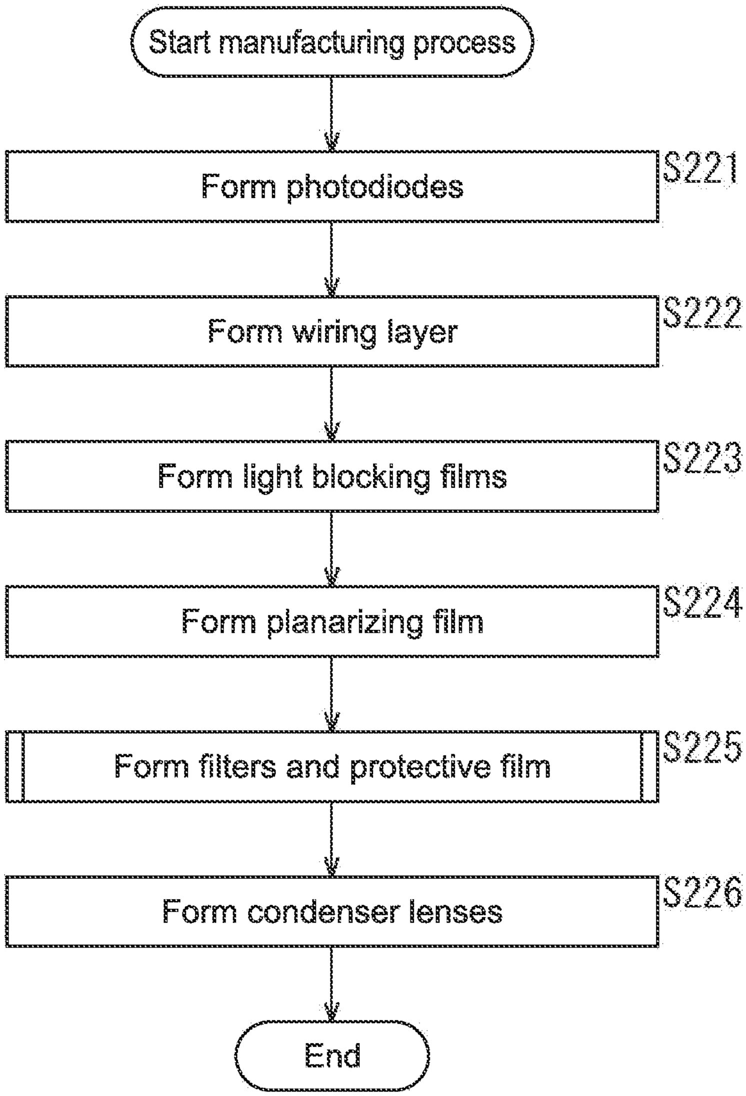

Start manufacturing process
Form photodiodes
S221
Form wiring layer
S222
Form light blocking films
S223
Form planarizing film
S224
Form filters and protective film
S225
Form condenser lenses
S226
End

FIG.12

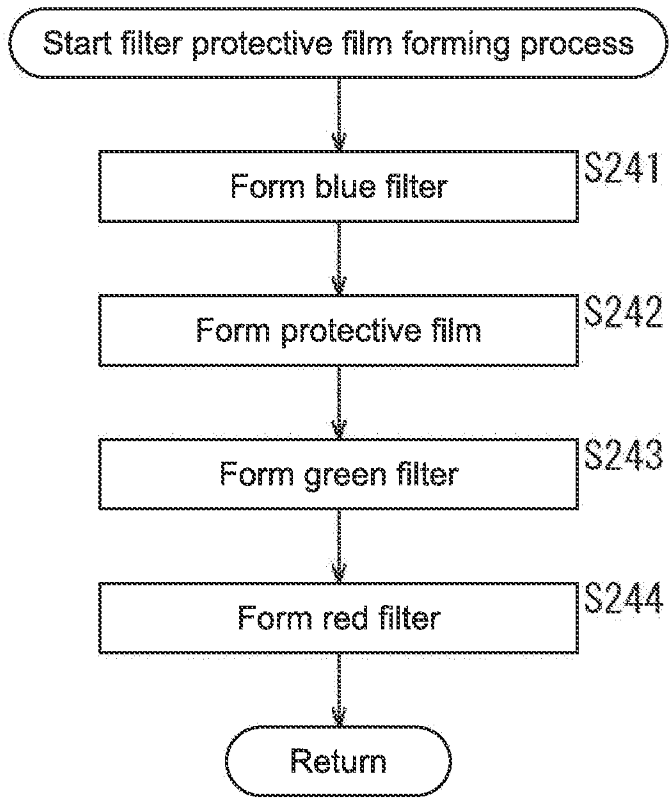

Start filter protective film forming process
Form blue filter
S241
Form protective film
S242
Form green filter
S243
Form red filter
S244
Return

FIG.13

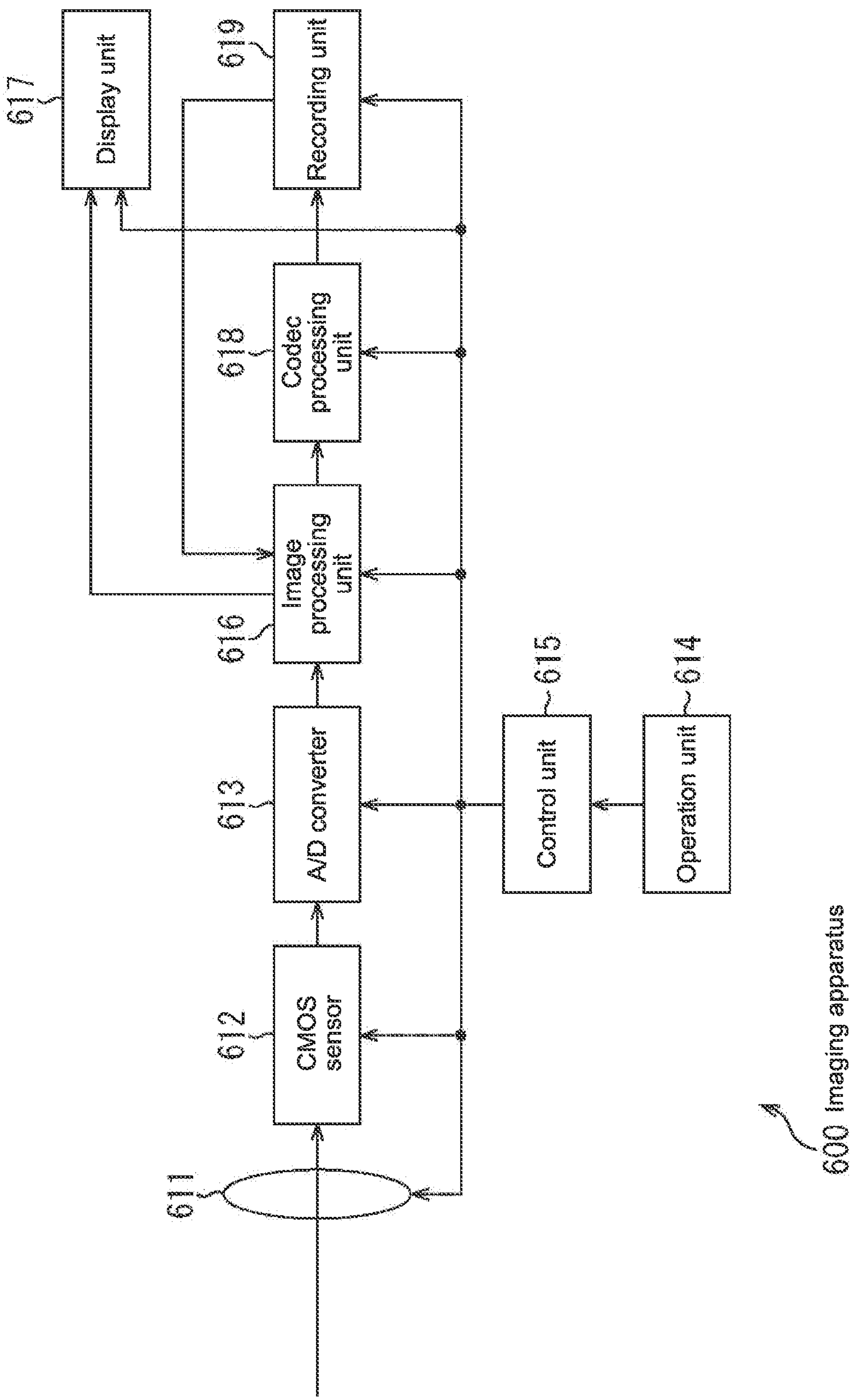

617
Display unit
619
Recording unit
618
Codec processing unit
616
Image processing unit
613
A/D converter
612
CMOS sensor
611
615
Control unit
614
Operation unit
600 Imaging apparatus

FIG. 14

IMAGE PICKUP ELEMENT, IMAGING APPARATUS, MANUFACTURING APPARATUS FOR IMAGE PICKUP ELEMENT, AND MANUFACTURING METHOD FOR IMAGE PICKUP ELEMENT

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Japanese Priority Patent Application JP 2013-158558 filed Jul. 31, 2013, the entire contents of which are incorporated herein by reference.

BACKGROUND

The present disclosure relates to an image pickup element, an imaging apparatus, a manufacturing apparatus for the image pickup element, and a manufacturing method for the image pickup element. More specifically, the present disclosure relates to an image pickup element, an imaging apparatus, a manufacturing apparatus for the image pickup element, and a manufacturing method for the image pickup element that enable suppression of deterioration in quality of captured images.

In relate art, in order to enhance sensitivity and shading characteristics of a solid-state image pickup element, there have been developed a method of reducing a distance between a condenser lens (microlens) and a photodiode (PD) that are provided in each pixel (i.e., a method of reducing height of solid-state image pickup element). In order to suppress deterioration in light collection efficiency, which may be caused by such height reduction, the possibility of increasing a refractive index of the microlens has been investigated.

Specifically, the possibility of forming the microlens with use of a silicon nitride (SiN) inorganic film having a high refractive index has been investigated. However, in that case, the microlens is difficult to form with high accuracy without a planarizing film configured to planarize surfaces of color filters (refer to, for example, Japanese Patent Application Laid-open No. 2008-277800). In addition, this planarizing film needs to have a film thickness of from approximately 200 nm to 300 nm so as to planarize the surfaces of the color filters. Therefore, height reduction of the solid-state image pickup element has been difficult to achieve.

In view of the circumstance, the possibility of forming the microlens with use of a resin system containing fine metal particles (refer to, for example, Japanese Patent Application Laid-open No. 2008-060464). In the case of using the resin system containing fine metal particles, the microlenses can be formed by spin coating, and hence is not liable to be influenced by steps on the surfaces of the color filters. Thus, the microlens can be formed with high accuracy without the planarizing film. As a result, height reduction of the solid-state image pickup element can be achieved.

SUMMARY

However, in the microlens formed with use of the resin containing fine metal particles, heat treatment after formation of the microlens may cause species of ions contained in the high refractive index resin to move into the photodiode (PD). As a result, dark current may be generated, and white spot deterioration may occur. In other words, quality of images captured via the solid-state image pickup element may be deteriorated.

There is a need to suppress deterioration in quality of captured images.

According to an embodiment of the present disclosure, there is provided an image pickup element, including: condenser lenses made of a resin containing fine metal particles; photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses; and a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate.

The protective film may have a non-flat surface at least on the condenser lens side.

The silicon compound may include any one of silicon dioxide ($SiO2$), silicon oxynitride (SiON), and silicon nitride (SiN).

The protective film may have a film thickness of 20 nm or more.

The image pickup element may further include optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough. The protective film may be formed between the condenser lenses and the optical filters.

The optical filters may at least include a color filter containing a dioxane pigment.

The color filter containing the dioxane pigment may include a blue color filter.

The image pickup element may further include a planarizing film formed between the optical filters and the silicon substrate. The protective film may include another protective film formed between the optical filters and the planarizing film.

The protective film may include still another protective film formed between the planarizing film and the silicon substrate.

The image pickup element may further include light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels. The still another protective film formed between the planarizing film and the silicon substrate may be formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

The image pickup element may further include a planarizing film formed between the optical filters and the silicon substrate. The protective film may include another protective film formed between the planarizing film and the silicon substrate.

The image pickup element may further include light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels. The other protective film formed between the planarizing film and the silicon substrate may be formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

The image pickup element may further include: optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and a planarizing film formed between the condenser lenses and the silicon substrate. The protective film may be formed to extend between one of the optical filters and corresponding one of the condenser lenses, between the one of the optical filters and another of the optical filters, and between the other of the optical filters and the planarizing film.

The protective film may include another protective film formed between the planarizing film and the silicon substrate.

The image pickup element may further include: optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and a planarizing film formed between the condenser lenses and the silicon substrate. The protective film may be formed between the optical filters and the planarizing film.

The protective film may include another protective film formed between the planarizing film and the silicon substrate.

The image pickup element may further include: optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and a planarizing film formed between the condenser lenses and the silicon substrate. The protective film may be formed between the planarizing film and the silicon substrate.

According to another embodiment of the present disclosure, there is provided an imaging apparatus, including: an image pickup element including condenser lenses made of a resin containing fine metal particles, photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses, and a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate; and an image processing unit configured to execute image processes on data items of images captured via the image pickup element.

According to still another embodiment of the present disclosure, there is provided a manufacturing apparatus configured to manufacture an image pickup element, the manufacturing apparatus including: a photoelectric-conversion-element forming unit configured to form, in a silicon substrate, photoelectric conversion elements configured to photoelectrically convert incident light; a protective film forming unit configured to form a protective film made of a silicon compound on an incident side of the silicon substrate in which the photoelectric conversion elements are formed by the photoelectric-conversion-element forming unit, the incident light entering the incident side of the silicon substrate; and a condenser lens forming unit configured to form condenser lenses each made of a resin containing fine metal particles on a side opposite to the silicon substrate side of the protective film formed by the protective film forming unit, the condenser lens being configured to condense the incident light.

According to yet another embodiment of the present disclosure, there is provided a manufacturing method for a manufacturing apparatus configured to manufacture an image pickup element, the manufacturing method including: forming, in a silicon substrate, photoelectric conversion elements configured to photoelectrically convert incident light; forming a protective film made of a silicon compound on an incident side of the silicon substrate in which the photoelectric conversion elements are formed, the incident light entering the incident side of the silicon substrate; and forming condenser lenses each made of a resin containing fine metal particles on a side opposite to the silicon substrate side of the protective film, the condenser lens being configured to condense the incident light.

The image pickup element according to the embodiment of the present disclosure includes: condenser lenses made of a resin containing fine metal particles; photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses; and a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate.

The imaging apparatus according to the other embodiment of the present disclosure includes: an image pickup element including condenser lenses made of a resin containing fine metal particles, photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses, and a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate; and an image processing unit configured to execute image processes on data items of images captured via the image pickup element.

The manufacturing apparatus according to the still another embodiment of the present disclosure is configured to manufacture an image pickup element. In the manufacturing apparatus, photoelectric conversion elements configured to photoelectrically convert incident light are formed in a silicon substrate, a protective film made of a silicon compound is formed on an incident side of the silicon substrate in which the photoelectric conversion elements are formed, the incident light entering the incident side of the silicon substrate, and condenser lenses each made of a resin containing fine metal particles are formed on a side opposite to the silicon substrate side of the protective film, the condenser lens being configured to condense the incident light.

According to the embodiments of the present disclosure, photographic subjects can be imaged, and in particular, quality of captured images can be suppressed from being deteriorated.

These and other objects, features and advantages of the present disclosure will become more apparent in light of the following detailed description of best mode embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a sectional view illustrating a configuration example of a part of an image pickup element;

FIGS. **2**A and **2**B illustrate an example of how a spectrum varies;

FIGS. **3**A-**3**C illustrate other examples of how a spectrum varies;

FIGS. **4**A and **4**B show examples of how dark current varies;

FIGS. **5**A-**5**C are sectional views illustrating main configuration examples of the image pickup element;

FIGS. **6**A and **6**B are sectional views illustrating other main configuration examples of the image pickup element;

FIGS. **7**A-**7**C are sectional views illustrating still other main configuration examples of the image pickup element;

FIGS. **8**A-**8**C are sectional views illustrating yet other main configuration examples of the image pickup element;

FIGS. **9**A and **9**B are sectional views illustrating yet other main configuration examples of the image pickup element;

FIG. **10** is a block diagram showing a main configuration example of a manufacturing apparatus;

FIG. **11** is a flowchart showing an example of a flow of a manufacturing process;

FIG. **12** is a flowchart showing another example of the flow of the manufacturing process;

FIG. **13** is a flowchart showing an example of a flow of a filter-and-protective-film forming process; and

FIG. **14** is a block diagram showing a main configuration example of an imaging apparatus.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments for carrying out the present disclosure (hereinafter, abbreviated as embodiments) will be described with reference to the drawings. Note that, the description is made in the following order.

1. First embodiment (Image pickup element)
2. Second embodiment (Manufacturing apparatus)
3. Third embodiment (Imaging apparatus)

1. First Embodiment

Height Reduction of Image Pickup Element and Influence Thereof

In relate art, in order to enhance sensitivity and shading characteristics of a solid-state image pickup element, there have been developed a method of reducing a distance between a condenser lens (microlens) and a photodiode (PD) that are provided in each pixel (i.e., a method of reducing height of solid-state image pickup element). Such height reduction may cause deterioration in light collection efficiency. In order to suppress such deterioration in light collection efficiency, the microlens should be reduced in radius of curvature or increased in refractive index.

The microlens is difficult to form to be rounder than a hemispherical shape. In other words, there is a limitation on the reduction in radius of curvature of the microlens. Further, in recent years, the pixels of the solid-state image pickup element have been further miniaturized, and hence the microlens has become more difficult to reduce in radius of curvature. In general, the microlens is made, for example, of a polystyrene resin and an acrylic resin, and those resins each have a refractive index n of from approximately 1.5 to 1.6. Thus, for example, when the solid-state image pickup element has a pixel unit size of approximately 1 μm, the radius of curvature of the microlens of each of the pixels may be larger than that of a hemisphere, which may cause difficulty in manufacture.

In view of the circumstances, the possibility of increasing the refractive index of the microlens has been investigated. Specifically, with use of a silicon nitride (SiN) inorganic film, a microlens having a high refractive index (for example, n=1.6 or more) can be formed.

Meanwhile, color filters (R, G, and B) used in the solid-state image pickup element generally have steps on their surfaces. When, for example, microlenses made of silicon nitride (SiN) are formed on the color filters having such steps, irregularities of the surfaces of the microlenses may be formed by influence of the steps of the color filters, which may cause difficulty in forming microlenses with high accuracy. As a countermeasure, in order to suppress the irregularities, as disclosed, for example, in Japanese Patent Application Laid-open No. 2008-277800, there has been devised formation of a planarizing film configured to planarize the surfaces of the color filters. When such a planarizing film is formed and the microlenses are formed thereon, the influence of the steps of the color filters is suppressed. As a result, the microlenses can be formed with higher accuracy.

However, in order to planarize the surfaces of the microlenses, the planarizing film needs to have a film thickness of from approximately 200 nm to 300 nm. Thus, the distance from the microlens to the photodiode (PD) increases (height reduction of the solid-state image pickup element is difficult), which causes difficulty in suppressing deterioration of the sensitivity and the shading characteristics. In other words, when the microlens is formed of a silicon nitride (SiN) inorganic film, the sensitivity and the shading characteristics may be deteriorated.

Further, as a method of increasing the refractive index of the microlenses, as disclosed, for example, in Japanese Patent Application Laid-open No. 2008-060464, there has been devised a method of forming the microlenses with use of a resin system containing fine metal particles. In a case of using the resin system containing fine metal particles, the microlenses can be formed by spin coating without being influenced by the steps on the surfaces of the color filters. Thus, the planarizing film configured to planarize the surfaces of the color filters can be omitted. As a result, the distance from the microlens to the photodiode (PD) can be reduced (height reduction of the solid-state image pickup element can be achieved), and the microlenses can be formed with high accuracy.

However, in the microlens formed of the resin containing fine metal particles, heat treatment after formation of the microlens may cause ions of species such as hydrogen (H) and fluorine (F) contained in the high refractive index resin to move into the photodiode (PD). As a result, dark current may be generated, and white spot deterioration may occur. Further, the ions of such species may be moved also into the color filters, which may cause spectral changes of the color filters. As a result, quality of images captured via the solid-state image pickup element may be deteriorated.

(Image Pickup Element)

As a countermeasure, in the image pickup element, a protective film made of a silicon compound is formed between the microlenses (condenser lenses) and a silicon substrate in which the photodiodes (photoelectric conversion elements) are formed.

FIG. **1** is a sectional view illustrating a main configuration example of pixels of an image pickup element to which the present technology is applied. The image pickup element **100** illustrated in FIG. **1** is a backside illumination type CMOS (Complementary Metal Oxide Semiconductor) image sensor configured to image a photographic subject and acquire captured images as electrical signals. The image pickup element **100** includes a plurality of pixels arranged, for example, in an array or a plane. In each of the pixels, incident light is photoelectrically converted to a pixel signal of a captured image. FIG. **1** illustrates an example of a layered structure of a light receiving part of the image pickup element **100** in cross-section. For the sake of convenience of description, the layered structure of FIG. **1** is schematically illustrated. Further, in FIG. **1**, for the sake of convenience of description, components (circuits, lines, or the like) configured to transmit charge obtained by the photoelectric conversion are omitted.

The light from the photographic subject enters the image pickup element **100** from top to bottom in FIG. **1**. FIG. **1** illustrates a configuration of two pixels, but the number of the pixels of the image pickup element **100** is not particularly limited. In general, three or more pixels, specifically, several hundreds of thousands of pixels, several millions of pixels, and several tens of millions of pixels are provided. Those numbers of pixels each basically have the same configuration as the configuration of the pixels illustrated in FIG. **1**.

As illustrated in FIG. **1**, the image pickup element **100** includes a silicon substrate **101**. The silicon substrate **101** includes a photodiode (PD) **102**A formed as a light receiving region (photoelectric conversion element configured to photoelectrically convert incident light) of the left pixel of FIG. **1**, and a photodiode (PD) **102**B formed as a light receiving region (photoelectric conversion element) of the right pixel of FIG. **1**. In the following, unless it is necessary to make distinctions between the photodiodes of those pixels, the photodiodes are referred to as photodiodes **102**. In other words, the photodiodes **102** formed in the silicon substrate **101** correspond respectively to the pixels.

Further, as illustrated in FIG. **1**, light blocking films **103**A to **103**C are formed on a light incident surface (upper side in FIG. **1**) of the silicon substrate **101**. The light blocking films are formed along pixel edge portions so as to partition the pixels. In other words, the light blocking films **103**A to **103**C illustrated in the sectional view of FIG. **1** are formed independently of each other between the pixels. However, actually, in accordance with arrangement of the pixels, light blocking films for all the pixels (or the light blocking films for some of the pixels) may be formed integrally with each other, for example, into a mesh-like pattern. In the following, unless it is necessary to make distinctions between the light blocking films for the pixels, the light blocking films **103**A to **103**C are referred to as light blocking films **103**.

The light blocking films **103** are each made of a material having excellent light blocking properties, and configured to suppress incident light from entering adjacent pixels.

As illustrated in FIG. **1**, the light blocking films **103** are formed on the light incident surface of the silicon substrate **101**. With this, irregularities are formed on this surface on the light incident side. As a countermeasure, in order to suppress the irregularities so as to planarize the surface, a planarizing film **104** is laminated on surfaces on the light incident side (upper side in FIG. **1**) of the silicon substrate **101** and the light blocking films **103**. The planarizing film **104** is made of a material having a high transmittance.

Further, optical filters each configured to limit a wavelength band of the incident light to be transmitted therethrough are formed on a surface on the light incident side (upper side in FIG. **1**) of the planarizing film **104**. In the example of FIG. **1**, a blue color filter **105**A is formed in the left pixel of FIG. **1**, and a green color filter **105**B is formed in the right pixel of FIG. **1**. Note that, in FIG. **1**, the letters ("Blue" and "Green") on the color filter **105**A and the color filter **105**B are added for the sake of convenience of description, and are not actually printed thereon.

The color filter **105**A is a color filter configured to transmit light in what is called a blue wavelength band (blue light). In other words, in the photodiode **102**A, the blue light that transmits through the color filter **105**A is photoelectrically converted. In still other words, the left pixel of FIG. **1** is a pixel configured to detect the blue light.

The color filter **105**B is a color filter configured to transmit light in what is called a green wavelength band (green light). In other words, in the photodiode **102**B, the green light that transmits through the color filter **105**B is photoelectrically converted. In still other words, the right pixel of FIG. **1** is a pixel configured to detect the green light.

In the following, unless it is necessary to make distinctions between the color filters of the pixels, the color filters **105**A and **105**B are referred to as color filters **105**. As illustrated in FIG. **1**, the color filters **105** formed respectively in the pixels of the image pickup element **100** are each configured to transmit light in any wavelength band (in other words, light of any color), and the colors of the color filters **105** may be arbitrarily selected. For example, color filters **105** of yellow, white, and other colors may be formed. Further, the colors of the color filters **105** may be arbitrarily employed in any other combinations. In general, color filters **105** of three colors of red (R), green (G), and blue (B) are used in many cases, but four or more colors, or two or less colors may be employed.

Thus, although FIG. **1** illustrates only the blue pixel and the green pixel, pixels of other colors may be provided depending on the combinations of the colors of the color filters **105**. For example, in a case where the color filters **105** of three colors of red (R), green (G), and blue (B) are used, the image pickup element **100** includes a red pixel provided with a red color filter (not shown) in addition to the pixels illustrated in FIG. **1**. As a matter of course, the pixels of the respective colors each need not necessarily include one pixel of the corresponding color, and the pixels of the respective colors each generally include a plurality of pixels of the corresponding color.

Further, instead of the color filters **105**, there may be formed optical filters configured to transmit or suppress light in a wavelength band other than that of visible light. For example, there may be formed filters configured to transmit ultraviolet light and infrared light, or there may be formed filters configured to block the ultraviolet light and the infrared light in contrast.

On a light incident surface side (upper side in FIG. **1**) of the color filters **105**, the condenser lenses (also referred to as microlenses) configured to increase light collection efficiency and to increase intensity of input light are provided respectively to the pixels. For example, a condenser lens **106**A is formed in the left pixel of FIG. **1**, and a condenser lens **106**B is formed in the right pixel of FIG. **1**. In the following, unless it is necessary to make distinctions between the condenser lenses of those pixels, the condenser lenses **106**A and **106**B are referred to as condenser lenses **106**.

In other words, the light from the photographic subject is condensed by the condenser lenses **106** and enters the pixels. This incident light is transmitted through the color filters **105**, the planarizing film **104**, and the like, and photoelectrically converted by the photodiodes **102**.

As described above, in order to increase the light collection efficiency, the condenser lenses **106** are made of the resin containing fine metal particles. The resin containing fine metal particles is a material having a refractive index higher than those of the polystyrene resin and the acrylic resin. Specifically, the refractive index at a wavelength of 500 nm falls within a range of from 1.6 to 2.0. Further, the transmittance of the resin containing fine metal particles is desirably as high as possible in a wavelength band of from 400 nm to 700 nm. For example, the transmittance is set to 90% or more.

The resin containing fine metal particles is obtained, for example, by adding particles of a metal compound to a copolymer resin and dispersing the added particles in the copolymer resin. Examples of the copolymer resin include an acrylic resin, a styrene resin, and a silane resin. Examples of the metal compound include titanium (Ti), magnesium (Mg), aluminum (Al), and zinc (Zn).

Actually, the color filters **105** are formed to have respective colors, and hence irregularities (steps in pixel units) are formed between the light incident surfaces (upper side in FIG. **1**) thereof. In this way, the light incident surfaces are non-flat. However, as described above, the resin containing fine metal particles can be applied by spin coating, and hence is not liable to be influenced by the steps on the surfaces of the color filters **105**. Thus, even without the planarizing film configured to planarize the light incident surfaces of the color filters **105**, the microlenses can be formed with high accuracy. As a result, height reduction of the image pickup element **100** can be achieved.

In addition, as illustrated in FIG. **1**, between the condenser lenses **106** and the color filters **105** of the image pickup element **100**, there is formed a protective film **110** configured to suppress the species of ions from moving from the condenser lenses **106**.

The protective film **110** is made of a silicon compound such as silicon dioxide (SiO2), silicon oxynitride (SiON), and silicon nitride (SiN). A surface on the light incident side (upper side in FIG. **1**) of the protective film **110** needs not be planarized, and hence there is no particular problem as long as a film thickness of approximately 20 nm or more is secured. In other words, the surface on the light incident side of the protective film **110** may be non-flat. In contrast, in order to planarize the surfaces of the color filters **105**, as described above, the planarizing film needs to have a film thickness of at least from approximately 200 nm to 300 nm. In other words, the protective film **110** can be formed to be much thinner than the planarizing film.

The protective film **110** is capable of suppressing the species of ions from moving from the condenser lenses **106**. Thus, influence of those species of ions on quality of images, such as spectral changes of the color filters **105**, and generation of dark current and white spots can be suppressed. As a result, quality of images captured via the image pickup element **100** can be suppressed from being deteriorated.

(Spectral Change)

Next, more detailed description is made of the influence of the species of ions on the color filters **105**. FIGS. **2**A and **2**B show an example of results of a simulation of the influence of the species of ions on the color filters **105** in a case where the protective film was not formed. In this simulation, an element configured as illustrated in FIG. **2**A was used as a model of an image pickup element in which the protective film was not formed. As illustrated in FIG. **2**A, this element was a laminate of a silicon substrate **121**, a blue color filter **122**, and a high refractive index resin **123** containing fine metal particles. The silicon substrate **121** was a model of the silicon substrate **101** (FIG. **1**), and provided with a photodiode (not shown) as well as the silicon substrate **101**. The color filter **122** was a model of the color filter **105**A (FIG. **1**). The high refractive index resin **123** containing fine metal particles was a model of the condenser lens **106**A.

Results of measurement of spectral characteristics of the color filter **122** of the element are shown in the graph of FIG. **2**B. In the graph of FIG. **2**B, the abscissa axis represents a wavelength, and the ordinate axis represents a transmittance. Further, a curve **124** shows measurement results before heat treatment, and a curve **125** shows measurement results after heating at 230° C. for ten minutes was performed as heat treatment to be executed in a process step of manufacturing an image pickup element (heat treatment after formation of the microlens). As shown in the graph of FIG. **2**B, a difference was observed between the spectral characteristics of the color filter **122** before the heating at 230° C. for ten minutes and the spectral characteristics thereof after the heating.

This spectral change was caused by movement of the ions of species (such as H and F) in the high refractive index resin **123** containing fine metal particles into the color filter **122** as a result of the heating. The spectral characteristics of the filter depend, for example, on its material. In other words, various materials are used for the filter in accordance with wavelength bands of light to be transmitted. In this case, when the material used therefor is liable to be influenced by the species of ions that move from the high refractive index resin **123** containing fine metal particles, the spectral change of the color filter **122** is liable to occur. Examples of such a material include a dioxane pigment (PV23). The dioxane pigment is used, for example, to obtain spectral characteristics of the blue color filter.

When the spectral change occurs in the color filter, a wavelength band of light to be photoelectrically converted by the photodiode is changed in accordance therewith. Thus, quality of captured images may be influenced thereby (specifically, quality of the images may be deteriorated).

FIGS. **3**A-**3**C show an example of results of simulations as in FIG. **2** in a case where the protective film is formed. In these simulations, an element configured as illustrated in FIG. **3**A was used as a model of an image pickup element in which the protective film was formed. As illustrated in FIG. **3**A, this element was obtained by additionally forming a protective film **126** between the blue color filter **122** and the high refractive index resin **123** containing fine metal particles in the laminate of FIG. **2**A. The protective film **126** as a model of the protective film **110** (FIG. **1**) was made of a silicon compound as well as the protective film **110**, and had a film thickness of approximately several tens of nm (20 nm or more).

When the protective film **126** is made of silicon oxynitride (SiON), as shown in the graph of FIG. **3**B, substantially no change was observed between the spectral characteristics of the color filter **122** before the heating at 230° C. for ten minutes (curve **124**) and the spectral characteristics thereof after the heating (curve **125**). Further, also when the protective film **126** was made of silicon nitride (SiN), as shown in the graph of FIG. **3**C, substantially no change was observed between the spectral characteristics of the color filter **122** before the heating at 230° C. for ten minutes (curve **124**) and the spectral characteristics thereof after the heating (curve **125**).

As described above, when the protective film made of a silicon compound is formed between the high refractive index resin **123** containing fine metal particles and the color filter **122**, the species of ions can be suppressed from moving from the high refractive index resin **123** containing fine metal particles into the color filter **122**. With this, the spectral changes of the color filter **122** can be suppressed. As a result, quality of captured images can be suppressed from being deteriorated.

(Dark Current)

Next, more detailed description is made of the influence of the species of ions on the photodiodes **102**. FIGS. **4**A and **4**B show results of examples of comparing how the influence of the species of ions on the photodiodes **102** changes depending on whether or not the protective film is formed. The graph of FIG. **4**A shows an example of results of a simulation of generating the dark current in the element configured as illustrated in FIG. **2**A (image pickup element in which the protective film **126** is not formed). In the graph of FIG. **4**A, the abscissa axis represents time, and the ordinate axis represents a dark current amount.

In this case, as shown in the graph of FIG. **4**A, as in the case of the simulations of the spectral change, substantially no dark current was generated under the state before the heat treatment at 230° C. for ten minutes. In contrast, the dark current was generated after the heat treatment. Measurements a plurality of times demonstrated that the dark current was generated while varying.

The graph of FIG. **4**B shows an example of results of a simulation of generating the dark current in the element configured as illustrated in FIG. **3**A (image pickup element in which the protective film **126** is formed). In the graph of FIG. **4**B, the abscissa axis represents time, and the ordinate axis represents the dark current amount.

In this case, as shown in the graph of FIG. **4**B, as in the case of the simulation of the spectral change, substantially no dark current was generated under either one of the states before and after the heat treatment at 230° C. for ten minutes.

As described above, when the protective film made of a silicon compound was formed between the high refractive index resin **123** containing fine metal particles and the photodiode (silicon substrate **121**), the species of ions were successfully suppressed from moving from the high refractive index resin **123** containing fine metal particles into the silicon substrate **121**. As a result, generation of the dark current and white spots was successfully suppressed.

From the results of the simulations described above, the same advantages can be obtained also in the image pickup element **100** of FIG. **1**. First, the condenser lenses **106** are formed with use of the resin containing fine metal particles. With this, as described above, height reduction of the image pickup element **100** can be achieved, and the condenser lenses **106** can be formed with high accuracy while enhancing sensitivity and shading characteristics. Further, refractive indices of the condenser lenses **106** also can be increased.

In addition, as described above, when the protective film **110** made of a silicon compound is additionally formed between the condenser lenses **106** and the color filters **105** (and the photodiodes **102**), the spectral changes of the color filters **105** can be suppressed, and generation of the dark current and white spots in the photodiodes **102** can be suppressed.

As a result, quality of images captured via the image pickup element **100** can be suppressed from being deteriorated.

(Protective Film)

As described above, the protective film made of a silicon compound may be formed as appropriate between a layer in which species of ions are generated (for example, layer of resin containing fine metal particles) and a layer into which the species of ions should not move (for example, layer of the color filters and layer of the silicon substrate in which photodiodes are formed). In other words, the protective film made of a silicon compound may be formed between any pair of the layer in which species of ions are generated and the layer into which the species of ions should not move.

Note that, as the protective film is formed between layers on the upper side (side closer to the layer in which species of ions are generated), the protective film is capable of suppressing the species of ions from moving into more of the layers. For example, as for the image pickup element **100** of FIG. **1**, the protective film **110** is capable of suppressing the species of ions in the condenser lenses **106** from moving into both layers of the color filters **105** and the silicon substrate **101**. Note that, as the protective film is formed between layers on a lower side (side farther from the layer in which the species of ions are generated), the protective film is capable of more reliably suppressing the species of ions from moving into the silicon substrate. Further, the protective film is capable of suppressing influence on layers that are not liable to be influenced by the species of ions.

Still further, the protective film may include a plurality of protective films (may be multi-layered). Note that, as the number of the protective films increases, a larger number of process steps need to be additionally executed, which may cause a cost increase. In addition, some or all of the protective films may be made of the same material, or may be made of materials different from each other.

Further, the film thickness of the protective film is not particularly limited. As the film thickness is larger, the species of ions can be more reliably suppressed from moving. In general, the species of ions can be sufficiently suppressed from moving with a thickness of approximately 20 nm or more.

(Other Examples of Position of Protective Film)

Although the protective film **110** is formed between the condenser lenses **106** and the color filters **105** in the description with reference to FIG. **1**, the position of the protective film **110** is not limited thereto. For example, the protective film **110** may be formed at positions as illustrated in FIGS. **5** to **9** below.

Specifically, as illustrated in FIGS. **5**A-**5**C, the protective film **110** may be bilayered. In the example of FIG. **5**A, a protective film **110-1** as a first layer is formed at the same position as that of the protective film **110** of FIG. **1** (between the condenser lenses **106** and the color filters **105**), and a protective film **110-2** as a second layer is formed between the color filters **105** and the planarizing film **104**. The protective films **110-1** and **110-2** are each a thin film similar to the protective film **110** (FIG. **1**), which is made, for example, of a silicon compound. The protective films **110-1** and **110-2** may be made of the same material, or may be made of materials different from each other. Further, the protective films **110-1** and **110-2** may have the same film thickness, or may have film thicknesses different from each other. In this case, the protective film **110-1** is capable of suppressing the species of ions in the condenser lenses **106** from moving into both the color filters **105** and the silicon substrate **101**. Further, the protective film **110-2** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

Further, in the example of FIG. **5**B, the protective film **110-1** as the first layer is formed at the same position as that in the case of FIG. **5**A, and the protective film **110-2** as the second layer is formed between the planarizing film **104** and a laminate of the light blocking films **103** and the silicon substrate **101**. In this case, the protective film **110-2** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

In addition, in this case, the protective film **110-2** is also capable of protecting the light blocking films **103**. Thus, a chemical liquid to be used in process steps of forming upper layers with respect thereto can be selected from a wider range of options (an acidic chemical liquid, a basic chemical liquid, and the like).

Further, in the example of FIG. **5**C, the protective film **110-1** as the first layer is formed at the same position as that in the case of FIG. **5**A, and the protective film **110-2** as the second layer is formed between the silicon substrate **101** and a laminate of the planarizing film **104** and the light blocking films **103**. Also in this case, the protective film **110-2** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

Alternatively, for example, as illustrated in FIGS. **6**A and **6**B, the protective film **110** may be tri-layered. In the example of FIG. **6**A, the protective film **110-1** as the first layer is formed at the same position as that in the case of FIG. **5**A, and the protective film **110-2** as the second layer is formed at the same position as that in the case of FIG. **5**A. In addition, a protective film **110-3** as a third layer is formed at the same position as that of the protective film **110-2** of FIG. **5**B (between the planarizing film **104** and the laminate of the light blocking films **103** and the silicon substrate **101**).

The protective films **110-1** to **110-3** are each a thin film similar to the protective film **110** (FIG. **1**), which is made, for example, of a silicon compound. The protective films **110-1** to **110-3** may be made of the same material, or may be made of materials different from each other. Further, the protective films **110-1** to **110-3** may have the same film thickness, or may have film thicknesses different from each other.

In this case, the protective film **110-3** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**. The protective film **110-3** is also capable of protecting the light blocking films **103**.

Further, in the example of FIG. **6**B, the protective film **110-1** as the first layer and the protective film **110-2** as the second layer are formed at the same positions as those in the case of FIG. **6**A, and the protective film **110-3** as the third layer is formed at the same position as that of the protective film **110-2** of FIG. **5**C (between the silicon substrate **101** and the laminate of the planarizing film **104** and the light blocking films **103**). Also in this case, the protective film **110-3** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

Still alternatively, for example, as illustrated in FIGS. **7**A-**7**C, the protective film **110** may be configured to protect only a color filter of a predetermined color among the color filters **105** (specifically, only a filter configured to transmit light in a predetermined wavelength band among a plurality of color filters configured to transmit light in wavelength bands different from each other).

As described above, various materials are used for the filter in accordance with wavelength bands of light to be transmitted. For example, a material liable to be influenced by the species of ions that move from the high refractive index resin **123** containing fine metal particles, such as the dioxane pigment, may be used only for some of the filters. In such a case, as in the example of FIG. **7**A, only the filter made of the material liable to be influenced by the species of ions may be protected with the protective film **110**.

In the example of FIG. **7**A, in a case where the blue color filter **105**A is the filter made of the material liable to be influenced by the species of ions (for example, the dioxane pigment), the protective film **110** is formed to protect only the blue color filter **105**A among the color filters **105**. Specifically, the protective film **110** is formed to extend between the condenser lens **106**A and the blue color filter **105**A, between the blue color filter **105**A and a color filter of a different color in an adjacent pixel (for example, the green color filter **105**B), and between the color filter of the different color in the adjacent pixel (for example, the green color filter **105**B) and the planarizing film **104**.

In this case, the protective film **110** is capable of suppressing the species of ions in the condenser lenses **106** from moving into both the blue color filter **105**A and the silicon substrate **101**.

Also in this case, the protective film **110** can be multilayered. Further, in the example of FIG. **7**B, the protective film **110-1** as the first layer is formed at the same position as that of the protective film **110** of FIG. **7**A, and the protective film **110-2** as the second layer is formed at the same position as that of the protective film **110-2** of FIG. **5**B (between the planarizing film **104** and the laminate of the light blocking films **103** and the silicon substrate **101**). In this case, the protective film **110-2** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**. Further, in this case, the protective film **110-2** is also capable of protecting the light blocking films **103**.

Further, in the example of FIG. **7**C, the protective film **110-1** as the first layer is formed at the same position as that of the protective film **110** of FIG. **7**A, and the protective film **110-2** as the second layer is formed at the same position as that of the protective film **110-2** of FIG. **5**C (between the silicon substrate **101** and the laminate of the planarizing film **104** and the light blocking films **103**). In this case, the protective film **110-2** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

Yet alternatively, for example, in a case where the color filters **105** are not liable to be influenced by the species of ions (for example, in a case where the color filters **105** do not contain the dioxane pigment), as illustrated in FIGS. **8**A-**8**C, the color filters **105** need not necessarily be protected with the protective film **110**. In the example of FIG. **8**A, the protective film **110**, which is formed at the same position as that of the protective film **110-2** of FIG. **5**A (between the color filters **105** and the planarizing film **104**), is formed as a single layer. In this case, the protective film **110** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

Further, in the example of FIG. **8**B, the protective film **110**, which is formed at the same position as that of the protective film **110-2** of FIG. **5**B (between the planarizing film **104** and the laminate of the light blocking films **103** and the silicon substrate **101**), is formed as a single layer. In this case, the protective film **110** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**. In addition, the protective film **110** is also capable of protecting the light blocking films **103**.

Still further, in the example of FIG. **8**C, the protective film **110**, which is formed at the same position as that of the protective film **110-2** of FIG. **5**C (between the silicon substrate **101** and the laminate of the planarizing film **104** and the light blocking films **103**), is formed as a single layer. In this case, the protective film **110** is capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

Also in this case, as illustrated in FIGS. **9**A-**9**B, the protective film **110** can be multilayered. Further, in the example of FIG. **9**A, the protective film **110-1** as the first layer is formed at the same position as that of the protective film **110** of FIG. **8**A (between the color filters **105** and the planarizing film **104**), and the protective film **110-2** as the second layer is formed at the same position as that of the protective film **110** of FIG. **8**B (between the planarizing film **104** and the laminate of the light blocking films **103** and the silicon substrate **101**). In this case, the protective films **110-1** and **110-2** are capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**. Further, the protective film **110-2** is also capable of protecting the light blocking films **103**.

Further, in the example of FIG. **9**B, the protective film **110-1** as the first layer is formed at the same position as that in the case of FIG. **9**A, and the protective film **110-2** as the second layer is formed at the same position as that of the protective film **110** of FIG. **8**C (between the silicon substrate **101** and the laminate of the planarizing film **104** and the light blocking films **103**). In this case, the protective films **110-1** and **110-2** are capable of suppressing the species of ions in the condenser lenses **106** from moving into the silicon substrate **101**.

2. Second Embodiment

Manufacturing Apparatus

FIG. **10** is a block diagram showing a main configuration example of a manufacturing apparatus configured to manufacture the image pickup element **100** (image sensor) to which the present technology is applied. A manufacturing apparatus **200** shown in FIG. **10** includes a control unit **201** and a manufacturing unit **202**.

The control unit **201** includes a CPU (Central Processing Unit), a ROM (Read Only Memory), and a RAM (Random Access Memory), and is configured to control units in the manufacturing unit **202** so as to execute processes of controlling manufacture of the image pickup element **100**. For example, the CPU of the control unit **201** is configured to execute various processes in accordance with programs stored in the ROM. Further, the CPU is configured also to execute various processes in accordance with programs loaded from a storage unit **213** to the RAM. The RAM is configured to store, as appropriate, for example, data that is used by the CPU at the time of executing the various processes.

The manufacturing unit **202** is configured to be controlled by the control unit **201** so as to execute the processes in the manufacture of the image pickup element **100**. The manufacturing unit **202** includes a photodiode forming unit **231**, a wiring layer forming unit **232**, a light-blocking-film forming unit **233**, a planarizing film forming unit **234**, a filter forming unit **235**, a condenser lens forming unit **236**, and a protective film forming unit **237**.

The photodiode forming unit **231** is configured to form the photodiodes **102** in the silicon substrate **101**. The wiring layer forming unit **232** is configured to form a wiring layer (not shown) on a surface on a side opposite to the light incident surface of the silicon substrate **101** (i.e., lower side in FIG. **1**). The light-blocking-film forming unit **233** is configured to form the light blocking films **103**. The planarizing film forming unit **234** is configured to form the planarizing film **104**. The filter forming unit **235** is configured to form the color filters **105**. The condenser lens forming unit **236** is configured to form the condenser lenses **106** made of the resin containing fine metal particles. The protective film forming unit **237** is configured to form the protective film **110**.

The photodiode forming unit **231** to the protective film forming unit **237** are controlled by the control unit **201** so as to execute the process steps of manufacturing the image pickup element **100**.

Further, the manufacturing apparatus **200** includes an input unit **211**, an output unit **212**, a storage unit **213**, a communication unit **214**, and a drive **215**.

Examples of the input unit **211** include a keyboard, a mouse, a touch panel, an external input terminal. The input unit **211** is configured to accept input of user's instructions and information items from the outside, and supply the instructions and the information items to the control unit **201**. Examples of the output unit **212** include displays such as a CRT (Cathode Ray Tube) display and an LCD (Liquid Crystal Display), a speaker, and an external output terminal. The output unit **212** is configured to output various information items supplied from the control unit **201** as images, voice, analog signals, or digital data.

The storage unit **213** includes a storage medium of any type such as a flash memory, an SSD (Solid State Drive), and a hard disk, and is configured to store the information items supplied from the control unit **201**, and to read and supply the stored information items in response to a request from the control unit **201**.

Examples of the communication unit **214** include an interface and a modem of a LAN (Local Area Network) or a wireless LAN. The communication unit **214** is configured to execute communication processes with external apparatus via networks including the Internet. Specifically, via the communication unit **214**, the information items supplied from the control unit **201** are sent to a communication counterpart, and information items received from the communication counterpart are supplied to the control unit **201**.

The drive **215** is configured to be connected as appropriate to the control unit **201**. A removable medium **221** such as a magnetic disk, an optical disk, a magneto-optical disk, and a semiconductor memory is mounted as appropriate to the drive **215**. Computer programs are loaded from the removable medium **221** through intermediation of the drive **215**, and installed as appropriate to the storage unit **213**.

(Flow **1** of Manufacturing Process)

With reference to the flowchart of FIG. **11**, description is made of a flow of a manufacturing process for the image pickup element **100**, which is executed by the manufacturing apparatus **200**. Note that, the flow of the manufacturing process shown in the flowchart of FIG. **11** is applied to a case of manufacturing the image pickup element **100** in the example of FIG. **1**.

Specifically, in this case, the protective film forming unit **237** acquires, from the filter forming unit **235**, an element in which the color filters **105** are laminated on a laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the light blocking films **103**, and the planarizing film **104**. Then, the protective film forming unit **237** forms and laminates the protective film **110** on the light incident surfaces (upper side in FIG. **1**) of the color filters **105** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110** to the condenser lens forming unit **236**.

After the manufacturing process is started, in Step S**201**, the control unit **201** controls the photodiode forming unit **231** so as to form the photodiodes **102** in the silicon substrate **101** correspondingly to respective pixels, the silicon substrate **101** being supplied from the outside.

In Step S**202**, the control unit **201** controls the wiring layer forming unit **232** so as to form and laminate the wiring layer (not shown) on the surface on the side opposite to the light incident surface of the silicon substrate **101** in which the photodiodes **102** are formed (lower side in FIG. **1**), the wiring layer including multi-layer wiring made of metals such as copper and aluminum.

In Step S**203**, the control unit **201** controls the light-blocking-film forming unit **233** so as to form the light blocking films **103** along the pixel edge portions on the light incident surface (upper side in FIG. **1**) of the silicon substrate **101**.

In Step S**204**, the control unit **201** controls the planarizing film forming unit **234** so as to form and laminate the planarizing film **104** on the light incident surface (upper side in FIG. **1**) of the silicon substrate **101** from above the light blocking films **103** in FIG. **1**, the light blocking films **103** also being formed on the light incident surface.

In Step S**205**, the control unit **201** controls the filter forming unit **235** so as to form and laminate the color filters **105** on the light incident surface (upper side in FIG. **1**) of the planarizing film **104**.

In Step S**206**, the control unit **201** controls the protective film forming unit **237** so as to form and laminate the protective film **110** on the light incident surfaces (upper side in FIG. **1**) of the color filters **105**.

In Step S**207**, the control unit **201** controls the condenser lens forming unit **236** so as to form the condenser lenses **106** on a light incident surface (upper side in FIG. **1**) of the protective film **110**.

After the process of Step S**207** is completed, the element provided with the condenser lenses **106** is supplied as the image pickup element **100** to the outside of the manufacturing apparatus **200**. Then, the manufacturing process is completed.

By the manufacturing process executed as described above by the manufacturing apparatus **200**, the image pickup element **100** (FIG. **1**) to which the present technology is applied can be obtained. Specifically, when the image pickup element **100** is manufactured as described above, height reduction and enhancement of both sensitivity and shading characteristics can be achieved, and the microlenses (condenser lenses **106**) each can be formed to have a high refractive index with high accuracy. In addition, generation of the spectral changes of the color filters **105**, and generation of the dark current and white spots in the photodiodes **102** can be suppressed. With this, the image pickup element **100** is capable of suppressing deterioration in quality of captured images.

Note that, the protective film **110** can be formed at other positions (between other layers) merely by executing the process of Step S**206** at timings different from that in the example of FIG. **11**. Further, the protective film **110** can be multilayered merely by repeatedly executing the process of Step S**206** at predetermined timings as many as the number of layers.

For example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **5**A, the protective film forming unit **237** acquires, from the planarizing film forming unit **234**, an element in which the planarizing film **104** is laminated on a laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder and the light blocking films **103**. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the filter forming unit **235**. After that, the protective film forming unit **237** acquires, from the filter forming unit **235**, the element in which the color filters **105** are laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the light blocking films **103**, the planarizing film **104**, and the protective film **110-2**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surfaces of the color filters **105** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the condenser lens forming unit **236**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**204** and the process of Step S**205** so as to form the protective film **110-2** but also between the process of Step S**205** and the process of Step S**207** so as to form the protective film **110-1**.

Further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **5**B, the protective film forming unit **237** acquires, from the light-blocking-film forming unit **233**, an element in which the light blocking films **103** are laminated on the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the silicon substrate **101** of the element, the light blocking films **103** also being formed on the light incident surface. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the planarizing film forming unit **234**. After that, the protective film forming unit **237** acquires, from the filter forming unit **235**, the element in which the color filters **105** are laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the light blocking films **103**, the protective film **110-2**, and the planarizing film **104**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surfaces of the color filters **105** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the condenser lens forming unit **236**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**203** and the process of Step S**204** so as to form the protective film **110-2** but also between the process of Step S**205** and the process of Step S**207** so as to form the protective film **110-1**.

Still further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **5**C, the protective film forming unit **237** acquires, from the wiring layer forming unit **232**, an element in which the wiring layer is formed under the silicon substrate **101** in which the photodiodes **102** are formed. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the silicon substrate **101** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the light-blocking-film forming unit **233**. After that, the protective film forming unit **237** acquires, from the filter forming unit **235**, the element in which the color filters **105** are laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the protective film **110-2**, the light blocking films **103**, and the planarizing film **104**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surfaces of the color filters **105** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the condenser lens forming unit **236**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**202** and the process of Step S**203** so as to form the protective film **110-2** but also between the process of Step S**205** and the process of Step S**207** so as to form the protective film **110-1**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **6**A, the protective film forming unit **237** acquires, from the light-blocking-film forming unit **233**, an element in which the light blocking films **103** are laminated on the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder. Then, the protective film forming unit **237** forms and laminates the protective film **110-3** on the light incident surface of the silicon substrate **101** of the element, the light blocking films **103** also being formed on the light incident surface. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-3** to the planarizing film forming unit **234**. After that, the protective film forming unit **237** acquires, from the planarizing film forming unit **234**, the element in which the planarizing film **104** is laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the light blocking films **103**, and the protective film **110-3**. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the filter forming unit **235**. After that, the protective film forming unit **237** acquires, from the filter forming unit **235**, the element in which the color filters **105** are laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the light blocking films **103**, the protective film **110-3**, the planarizing film **104**, and the protective film **110-2**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surfaces of the color filters **105** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the condenser lens forming unit **236**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**203** and the process of Step S**204** so as to form the protective film **110-3** but also between the process of Step S**204** and the process of Step S**205** so as to form the protective film **110-2** and between the process of Step S**205** and the process of Step S**207** so as to form the protective film **110-1**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **6**B, the protective film forming unit **237** acquires, from the wiring layer forming unit **232**, an element in which the wiring layer is formed under the silicon substrate **101** in which the photodiodes **102** are formed. Then, the protective film forming unit **237** forms and laminates the protective film **110-3** on the light incident surface of the silicon substrate **101** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-3** to the light-blocking-film forming unit **233**. After that, the protective film forming unit **237** acquires, from the planarizing film forming unit **234**, the element in which the planarizing film **104** is laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the protective film **110-3**, and the light blocking films **103**. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the filter forming unit **235**. After that, the protective film forming unit **237** acquires, from the filter forming unit **235**, the element in which the color filters **105** are laminated on the laminate of on the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the protective film **110-3**, the light blocking films **103**, the planarizing film **104**, and the protective film **110-2**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surfaces of the color filters **105** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the condenser lens forming unit **236**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**202** and the process of Step S**203** so as to form the protective film **110-3** but also between the process of Step S**204** and the process of Step S**205** so as to form the protective film **110-2** and between the process of Step S**205** and the process of Step S**207** so as to form the protective film **110-1**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **8**A, the protective film forming unit **237** acquires, from the planarizing film forming unit **234**, an element in which the planarizing film **104** is laminated on a laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder and the light blocking films **103**. Then, the protective film forming unit **237** forms and laminates the protective film **110** on the light incident surface of the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110** to the filter forming unit **235**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** between the process of Step S**204** and the process of Step S**205** so as to form the protective film **110**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **8**B, the protective film forming unit **237** acquires, from the light-blocking-film forming unit **233**, an element in which the light blocking films **103** are laminated on the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder. Then, the protective film forming unit **237** forms and laminates the protective film **110** on the light incident surface of the silicon substrate **101** of the element, the light blocking films **103** also being formed on the light incident surface. Next, the protective film forming unit **237** supplies the element provided with the protective film **110** to the planarizing film forming unit **234**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** between the process of Step S**203** and the process of Step S**204** so as to form the protective film **110**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **8**C, the protective film forming unit **237** acquires, from the wiring layer forming unit **232**, an element in which the wiring layer is formed under the silicon substrate **101** in which the photodiodes **102** are formed. Then, the protective film forming unit **237** forms and laminates the protective film **110** on the light incident surface of the silicon substrate **101** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110** to the light-blocking-film forming unit **233**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** between the process of Step S**202** and the process of Step S**203** so as to form the protective film **110**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **9**A, the protective film forming unit **237** acquires, from the light-blocking-film forming unit **233**, an element in which the light blocking films **103** are laminated on the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the silicon substrate **101** of the element, the light blocking films **103** also being formed on the light incident surface. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the planarizing film forming unit **234**. After that, the protective film forming unit **237** acquires, from the planarizing film forming unit **234**, the element in which the planarizing film **104** is laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the light blocking films **103**, and the protective film **110-2**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surface of the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the filter forming unit **235**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**203** and the process of Step S**204** so as to form the protective film **110-2** but also between the process of Step S**204** and the process of Step S**205** so as to form the protective film **110-1**.

Yet further, for example, in order to manufacture the image pickup element **100** of the configuration example of FIG. **9**B, the protective film forming unit **237** acquires, from the wiring layer forming unit **232**, an element in which the wiring layer is formed under the silicon substrate **101** in which the photodiodes **102** are formed. Then, the protective film forming unit **237** forms and laminates the protective film **110-2** on the light incident surface of the silicon substrate **101** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-2** to the light-blocking-film forming unit **233**. After that, the protective film forming unit **237** acquires, from the planarizing film forming unit **234**, the element in which the planarizing film **104** is laminated on the laminate of the silicon substrate **101** in which the photodiodes **102** are formed and which is provided with the wiring layer thereunder, the protective film **110-2**, the light blocking films **103**, and the planarizing film **104**. Then, the protective film forming unit **237** forms and laminates the protective film **110-1** on the light incident surface of the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110-1** to the filter forming unit **235**.

In other words, with reference to the flowchart of FIG. **11**, the protective film forming unit **237** executes the process of Step S**206** not only between the process of Step S**202** and the process of Step S**203** so as to form the protective film **110-2** but also between the process of Step S**204** and the process of Step S**205** so as to form the protective film **110-1**.

(Flow **2** of Manufacturing Process)

Note that, the image pickup elements **100** in the examples of FIG. **7** can be manufactured merely by executing the process of Step S**205** and the process of Step S**206** of FIG. **11** parallel to each other. With reference to the flowchart of FIG. **12**, description is made of an example of the flow of the manufacturing process in that case. The flowchart of FIG. **12** shows an example of the flow of the manufacturing process for the image pickup elements **100** in the examples of FIG. **7**.

Specifically, in this case, the protective film forming unit **237** acquires, from the filter forming unit **235**, an element in which one of the color filters **105** is formed at a predetermined part (pixel) on the light incident surface (upper side in FIG. **7**A) of the planarizing film **104** (for example, color filter **105**A is formed in the left pixel of FIG. **7**A). Then, the protective film forming unit **237** forms and laminates the protective film **110** from the light incident surface side (upper side in FIG. **7**A) of the color filter **105**A and the planarizing film **104** of the element. Next, the protective film forming unit **237** supplies the element provided with the protective film **110** to the filter forming unit **235**. The filter forming unit **235** forms and laminates the rest of the color filters **105** (for example, color filter **105**B) on predetermined parts (pixels) on the light incident surface of the protective film **110**.

After the manufacturing process is started, the processes of Steps S**221** to S**224** are executed similar to the processes of Steps S**201** to S**204** in FIG. **11**. With this, the photodiodes **102** are formed in the silicon substrate **101**, and the wiring layer, the light blocking films **103**, and the planarizing film **104** are formed.

In Step S**225**, the control unit **201** controls the filter forming unit **235** and the protective film forming unit **237** so as to execute a filter-and-protective-film forming process. With this, the color filters **105** and the protective film **110** are formed and laminated on the light incident surface (upper side in FIG. **7**A) of the planarizing film **104**.

After the color filters **105** and the protective film **110** are formed as illustrated in FIG. **7**A, in Step S**226**, the control unit **201** controls the condenser lens forming unit **236** so as to form the condenser lenses **106** on the light incident surfaces (upper side in FIG. **7**A) of the color filters **105** and the protective film **110**.

After the process of Step S**226** is completed, the element provided with the condenser lenses **106** is supplied as the image pickup element **100** to the outside of the manufacturing apparatus **200**. Then, the manufacturing process is completed.

(Flow of Filter-and-Protective-Film Forming Process)

Next, with reference to the flowchart of FIG. **13**, description is made of an example of a flow of the filter-and-protective-film forming process to be executed in Step S**225** in FIG. **12**. Note that, the flow of the flowchart of FIG. **13** shows a process in a case of forming color filters of three colors of red (R), green (G), and blue (B) as the color filters **105**.

After the filter-and-protective-film forming process is started, in Step S**241**, the filter forming unit **235** forms and laminates a blue filter (in the example of FIG. **7**A, color filter **105**A) on a predetermined part (pixel) on the light incident surface (upper side in FIG. **7**A) of the planarizing film **104**.

In Step S**242**, the protective film forming unit **237** forms and laminates the protective film **110** on the light incident surface (upper side in FIG. **7**A) of the planarizing film **104**, on a part of which the blue filter (color filter **105**A) is formed in Step S**241** (in other words, laminates the protective film **110** on both the planarizing film **104** and the color filter **105**A).

In Step S**243**, the filter forming unit **235** forms and laminates a green filter (in the example of FIG. **7**A, color filter **105**B) on a predetermined part (pixel) on the light incident surface (upper side in FIG. **7**A) of the protective film **110** formed in Step S**242**.

In Step S**244**, the filter forming unit **235** forms and laminates a red filter on another predetermined part (pixel) on the light incident surface (upper side in FIG. **7**A) of the protective film **110** formed in Step S**242**.

After the color filters **105** of the three colors and the protective film **110** are formed, the filter-and-protective-film forming process is completed. Then, the flow proceeds to Step S**226**.

By the processes executed as described above by the manufacturing apparatus **200**, the image pickup element **100** (FIG. **7**A) to which the present technology is applied can be obtained. Specifically, when the image pickup element **100** is manufactured as described above, height reduction and enhancement of both sensitivity and shading characteristics can be achieved, and the microlenses (condenser lenses **106**) each can be formed to have a high refractive index with high accuracy. In addition, generation of the spectral changes of the color filters **105** each configured to define a predetermined band, and generation of the dark current and white spots in the photodiodes **102** can be suppressed. With this, the image pickup element **100** is capable of suppressing deterioration in quality of captured images.

Note that, in the flowchart of FIG. **13**, either the process of Step S**243** or the process of Step S**244** may be executed first. In other words, the processes may be executed in any order as long as the process of forming the filter to be protected by the protective film **110** on a side opposite to the condenser lens

106 side of the protective film 110 is executed prior to Step S242, and the processes of forming the filters not to be protected by the protective film 110 are executed subsequently to Step S242.

Thus, for example, in order to protect the green filter (color filter 105B), the process of Step S243 is executed prior to the process of Step S242, and the process of Step S241 and the process of Step S244 are executed subsequently to the process of Step S242. Further, for example, in order to protect the red filter, the process of Step S244 is executed prior to the process of Step S242, and the process of Step S241 and the process of Step S243 are executed subsequently to the process of Step S242. The same applies to a case where the colors of the color filters 105 are used in other combinations, and also to a case where the filter forming unit 235 forms filters other than the color filters 105.

In addition, as in the examples of FIGS. 7B and 7C, in order to form additional protective films at positions other than that of the protective film 110 of FIG. 7A, in addition to the processes of Steps of FIG. 12, the process of Step S206 of FIG. 11 is executed at a predetermined timing.

Specifically, in order to manufacture the image pickup element 100 of the configuration example of FIG. 7B, the protective film forming unit 237 acquires, from the light-blocking-film forming unit 233, an element in which the light blocking films 103 are laminated on the silicon substrate 101 in which the photodiodes 102 are formed and which is provided with the wiring layer thereunder. Then, the protective film forming unit 237 forms and laminates the protective film 110-2 on the light incident surface of the silicon substrate 101 of the element, the light blocking films 103 also being formed on the light incident surface. Next, the protective film forming unit 237 supplies the element provided with the protective film 110-2 to the planarizing film forming unit 234. After that, the protective film forming unit 237 acquires, from the filter forming unit 235, the element in which one of the color filters 105 is formed at a predetermined part (pixel) on the light incident surface of the planarizing film 104 (for example, color filter 105A is formed). Then, the protective film forming unit 237 forms and laminates the protective film 110-1 on the element, specifically, on the light incident surfaces (upper side in FIG. 7B) of the color filters 105 (color filter 105A) and the planarizing film 104. Next, the protective film forming unit 237 supplies the element provided with the protective film 110-1 to the filter forming unit 235. The filter forming unit 235 forms and laminates the rest of the color filters 105 (for example, color filter 105B) on predetermined parts (pixels) on the light incident surface of the protective film 110.

In other words, with reference to the flowchart of FIG. 12, the protective film forming unit 237 executes the process of Step S206 of FIG. 11 between the process of Step S223 and the process of Step S224 so as to form the protective film 110-2, and executes the filter-and-protective-film forming process of Step S225 so as to form the protective film 110-1.

Further, specifically, in order to manufacture the image pickup element 100 of the configuration example of FIG. 7C, the protective film forming unit 237 acquires, from the wiring layer forming unit 232, an element in which the wiring layer is formed under the silicon substrate 101 in which the photodiodes 102 are formed. Then, the protective film forming unit 237 forms and laminates the protective film 110-2 on the light incident surface of the silicon substrate 101 of the element. Next, the protective film forming unit 237 supplies the element provided with the protective film 110-2 to the light-blocking-film forming unit 233. After that, the protective film forming unit 237 acquires, from the filter forming unit 235, the element in which one of the color filters 105 is formed at a predetermined part (pixel) on the light incident surface of the planarizing film 104 (for example, color filter 105A is formed). Then, the protective film forming unit 237 forms and laminates the protective film 110-1 on the element, specifically, on the light incident surfaces (upper side in FIG. 7C) of the color filters 105 (color filter 105A) and the planarizing film 104. Next, the protective film forming unit 237 supplies the element provided with the protective film 110-1 to the filter forming unit 235. The filter forming unit 235 forms and laminates the rest of the color filters 105 (for example, color filter 105B) on predetermined parts (pixels) on the light incident surface of the protective film 110.

In other words, with reference to the flowchart of FIG. 12, the protective film forming unit 237 executes the process of Step S206 of FIG. 11 between the process of Step S222 and the process of Step S223 so as to form the protective film 110-2, and executes the filter-and-protective-film forming process of Step S225 so as to form the protective film 110-1.

3. Third Embodiment

Imaging Apparatus

The image pickup element 100 (image sensor) manufactured as described above with the present technology is applicable to devices such as an imaging apparatus. In other words, the present technology can be carried out not only as an image pickup element but also as a device using the image pickup element (for example, imaging apparatus).

FIG. 14 is a block diagram showing a main configuration example of the imaging apparatus. An imaging apparatus 600 shown in FIG. 14 is an apparatus configured to image a photographic subject and output images of the photographic subject as electrical signals.

As shown in FIG. 14, the imaging apparatus 600 include an optical unit 611, a CMOS sensor 612, an A/D converter 613, an operation unit 614, a control unit 615, an image processing unit 616, a display unit 617, a codec processing unit 618, and a recording unit 619.

The optical unit 611 includes a lens configured to adjust a focal point with respect to a photographic subject and condense light beams from a focal position, an aperture configured to adjust exposure, and a shutter configured to control a image capturing timing. The optical unit 611 is configured to transmit light (incident light) therethrough from the photographic subject to the CMOS sensor 612.

The CMOS sensor 612 is configured to photoelectrically convert the incident light to a signal of each of the pixels (pixel signal), and transmit the signal to the A/D converter 613.

The A/D converter 613 is configured to convert the pixel signals supplied at predetermined timings from the CMOS sensor 612 to digital data items (image data items), and sequentially supply the data items to the image processing unit 616 at predetermined timings.

Examples of the operation unit 614 include a jog dial (trademark), keys, buttons, and a touch panel. The operation unit 614 is configured to accept input by a user, and transmit signals corresponding to the operation input to the control unit 615.

The control unit 615 is configured to drive and control, in response to the signals corresponding to the operation input via the operation unit 614 by the user, the optical unit 611, the CMOS sensor 612, the A/D converter 613, the image processing unit 616, the display unit 617, the codec processing unit 618, and the recording unit 619 so as to cause those units to execute imaging processes.

The image processing unit **616** is configured to execute various image processes such as color mixture correction, black level correction, white balance adjustment, a demosaic process, a matrix process, gamma correction, YC conversion on the image data items supplied from the A/D converter **613**. The image processing unit **616** is configured also to supply the image data items subjected to the image processes to the display unit **617** and the codec processing unit **618**.

Examples of the display unit **617** include a liquid crystal display. The display unit **617** is configured to display images of the photographic subject based on the image data items supplied from the image processing unit **616**.

The codec processing unit **618** is configured to execute an encoding process according to a predetermined method on the image data items supplied from the image processing unit **616**, and supply the encoded data items thus obtained to the recording unit **619**.

The recording unit **619** is configured to record the encoded data items from the codec processing unit **618**. The encoded data items recorded in the recording unit **619** is read and decoded as appropriate by the image processing unit **616**. Image data items obtained by the decoding process are supplied to the display unit **617**, and images corresponding thereto are displayed.

The present technology described above is applied to the CMOS sensor **612** of the imaging apparatus **600** as described above. In other words, the image pickup element **100** to which the present technology is applied is used as the CMOS sensor **612**. Specifically, the CMOS sensor **612** includes the condenser lenses each made of the resin containing fine metal particles, and the protective film made of a silicon compound and formed between the condenser lenses and the filters or the photodiodes. Thus, height reduction and enhancement of both sensitivity and shading characteristics can be achieved, and the microlenses (condenser lenses **106**) each can be formed to have a high refractive index with high accuracy. In addition, generation of the spectral changes of the color filters **105**, and generation of the dark current and white spots in the photodiodes **102** can be suppressed. With this, the CMOS sensor **612** is capable of suppressing deterioration in quality of captured images. As a result, images of the photographic subject are captured in higher quality with the imaging apparatus **600**.

Note that, the imaging apparatus to which the present technology is applied is not limited to the configuration described above, and other configurations may be employed. For example, the imaging apparatus is applicable not only to digital still cameras and digital camcorders, but also to information processing apparatus having an imaging function, such as a mobile phone, a smartphone, a tablet device, and a personal computer. Further, the imaging apparatus is applicable to a camera module to be used by being mounted to other information processing apparatus (or to be incorporated therein as a built-in device).

Note that, the "system" in this specification refers to an entire apparatus including a plurality of devices (apparatus).

Further, a configuration described as a single apparatus (or processing unit) hereinabove may be divided into a plurality of apparatus (or processing units). In contrast, configurations described as a plurality of apparatus (or processing units) hereinabove may be integrated into a single apparatus (or processing unit). Still further, as a matter of course, configurations other than those described hereinabove may be added to the configurations of the apparatus (or processing units). Yet further, as long as the configurations and operations of the entire system are substantially unchanged, a part of a configuration of a certain apparatus (or processing unit) may be incorporated in a configuration of another apparatus (or another processing unit). In other words, the embodiments of the present technology are not limited to the embodiments described hereinabove, and various modifications may be made thereto without departing from the gist of the present technology.

The present technology may include the following configurations.

(1) An image pickup element, including:

condenser lenses made of a resin containing fine metal particles;

photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses; and

a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate.

(2) The image pickup element according to any one of Item (1) and Items (3) to (27), in which the protective film has a non-flat surface at least on the condenser lens side.

(3) The image pickup element according to any one of Items (1) and (2) and Items (4) to (27), in which the silicon compound includes any one of silicon dioxide (SiO2), silicon oxynitride (SiON), and silicon nitride (SiN).

(4) The image pickup element according to any one of Items (1) to (3) and Items (5) to (27), in which the protective film has a film thickness of 20 nm or more.

(5) The image pickup element according to any one of Items (1) to (4) and Items (6) to (27), further including optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough, in which

the protective film is formed between the condenser lenses and the optical filters.

(6) The image pickup element according to any one of Items (1) to (5) and Items (7) to (27), in which the optical filters at least include a color filter containing a dioxane pigment.

(7) The image pickup element according to any one of Items (1) to (6) and Items (8) to (27), in which the color filter containing the dioxane pigment includes a blue color filter.

(8) The image pickup element according to any one of Items (1) to (7) and Items (9) to (27), further including a planarizing film formed between the optical filters and the silicon substrate, in which

the protective film includes another protective film formed between the optical filters and the planarizing film.

(9) The image pickup element according to any one of Items (1) to (8) and Items (10) to (27), in which the protective film includes still another protective film formed between the planarizing film and the silicon substrate.

(10) The image pickup element according to any one of Items (1) to (9) and Items (11) to (27), further including light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, in which

the still another protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

(11) The image pickup element according to any one of Items (1) to (10) and Items (12) to (27), further including a planarizing film formed between the optical filters and the silicon substrate, in which

the protective film includes another protective film formed between the planarizing film and the silicon substrate.

(12) The image pickup element according to any one of Items (1) to (11) and Items (13) to (27), further including light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, in which

the other protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

(13) The image pickup element according to any one of Items (1) to (12) and Items (14) to (27), further including:

optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and

a planarizing film formed between the condenser lenses and the silicon substrate, in which

the protective film is formed to extend between one of the optical filters and corresponding one of the condenser lenses, between the one of the optical filters and another of the optical filters, and between the other of the optical filters and the planarizing film.

(14) The image pickup element according to any one of Items (1) to (13) and Items (15) to (27), in which the one of the optical filters at least includes a color filter containing a dioxane pigment.

(15) The image pickup element according to any one of Items (1) to (14) and Items (16) to (27), in which the color filter containing the dioxane pigment includes a blue color filter.

(16) The image pickup element according to any one of Items (1) to (15) and Items (17) to (27), in which the protective film includes another protective film formed between the planarizing film and the silicon substrate.

(17) The image pickup element according to any one of Items (1) to (16) and Items (18) to (27), further including light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, in which

the other protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

(18) The image pickup element according to any one of Items (1) to (17) and Items (19) to (27), further including:

optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and

a planarizing film formed between the condenser lenses and the silicon substrate, in which

the protective film is formed between the optical filters and the planarizing film.

(19) The image pickup element according to any one of Items (1) to (18) and Items (20) to (27), in which the protective film includes another protective film formed between the planarizing film and the silicon substrate.

(20) The image pickup element according to any one of Items (1) to (19) and Items (21) to (27), further including light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, in which

the other protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

(21) The image pickup element according to any one of Items (1) to (20) and Items (22) to (27), further including:

optical filters each formed between corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and

a planarizing film formed between the condenser lenses and the silicon substrate, in which

the protective film is formed between the planarizing film and the silicon substrate.

(22) The image pickup element according to any one of Items (1) to (21) and Items (23) to (27), further including light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, in which

the protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

(23) The image pickup element according to any one of Items (1) to (22) and Items (24) to (27), in which the resin containing fine metal particles is obtained by adding particles of a metal compound to a copolymer resin and dispersing the added particles of the metal compound in the copolymer resin.

(24) The image pickup element according to any one of Items (1) to (23) and Items (25) to (27), in which the copolymer resin includes any one of an acrylic resin, a styrene resin, and a silane resin.

(25) The image pickup element according to any one of Items (1) to (24) and Items (26) and (27), in which the metal compound includes any one of titanium (Ti), magnesium (Mg), aluminum (Al), and zinc (Zn).

(26) The image pickup element according to any one of Items (1) to (25), and Item (27), in which the resin containing fine metal particles has a refractive index within a range of from 1.6 to 2.0 at a wavelength of 500 nm.

(27) The image pickup element according to any one of Items (1) to (26), in which the resin containing fine metal particles has a transmittance of 90% or more in a wavelength band of from 400 nm to 700 nm.

(28) An imaging apparatus, including:

an image pickup element including

condenser lenses made of a resin containing fine metal particles,

photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enter from an outside through corresponding one of the condenser lenses, and

a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate; and

an image processing unit configured to execute image processes on data items of images captured via the image pickup element.

(29) A manufacturing apparatus configured to manufacture an image pickup element, the manufacturing apparatus including:

a photoelectric-conversion-element forming unit configured to form, in a silicon substrate, photoelectric conversion elements configured to photoelectrically convert incident light;

a protective film forming unit configured to form a protective film made of a silicon compound on an incident side of the silicon substrate in which the photoelectric conversion elements are formed by the photoelectric-conversion-element forming unit, the incident light entering the incident side of the silicon substrate; and

a condenser lens forming unit configured to form condenser lenses each made of a resin containing fine metal particles on a side opposite to the silicon substrate side of the protective film formed by the protective film forming unit, the condenser lens being configured to condense the incident light.

(30) A manufacturing method for a manufacturing apparatus configured to manufacture an image pickup element, the manufacturing method including:

forming, in a silicon substrate, photoelectric conversion elements configured to photoelectrically convert incident light;

forming a protective film made of a silicon compound on an incident side of the silicon substrate in which the photoelectric conversion elements are formed, the incident light entering the incident side of the silicon substrate; and

forming condenser lenses each made of a resin containing fine metal particles on a side opposite to the silicon substrate side of the protective film, the condenser lens being configured to condense the incident light.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. An image pickup element, comprising:

condenser lenses made of a resin containing fine metal particles;

photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enters from an outside through a corresponding one of the condenser lenses;

a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate; and

optical filters each formed between a corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough, wherein

the protective film is formed between the condenser lenses and the optical filters.

2. The image pickup element according to claim **1**, wherein the protective film has a non-flat surface at least on the condenser lens side.

3. The image pickup element according to claim **1**, wherein the silicon compound includes any one of silicon dioxide (SiO2), silicon oxynitride (SiON), and silicon nitride (SiN).

4. The image pickup element according to claim **3**, wherein the protective film has a film thickness of 20 nm or more.

5. The image pickup element according to claim **1**, wherein the optical filters at least include a color filter containing a dioxane pigment.

6. The image pickup element according to claim **5**, wherein the color filter containing the dioxane pigment includes a blue color filter.

7. The image pickup element according to claim **1**, further comprising a planarizing film formed between the optical filters and the silicon substrate, wherein the protective film includes another protective film formed between the optical filters and the planarizing film.

8. The image pickup element according to claim **7**, wherein the protective film includes still another protective film formed between the planarizing film and the silicon substrate.

9. The image pickup element according to claim **8**, further comprising light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, wherein

the still another protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

10. The image pickup element according to claim **1**, further comprising a planarizing film formed between the optical filters and the silicon substrate, wherein the protective film includes another protective film formed between the planarizing film and the silicon substrate.

11. The image pickup element according to claim **10**, further comprising light blocking films formed along pixel edge portions between the planarizing film and the silicon substrate and configured to suppress the incident light from entering adjacent pixels, wherein

the other protective film formed between the planarizing film and the silicon substrate is formed between the planarizing film and a laminate of the light blocking films and the silicon substrate.

12. An image pickup element, comprising:

condenser lenses made of a resin containing fine metal particles;

photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enters from an outside through a corresponding one of the condenser lenses;

a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate;

optical filters each formed between a corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough; and

a planarizing film formed between the condenser lenses and the silicon substrate, wherein

the protective film is formed to extend between one of the optical filters and corresponding one of the condenser lenses, between the one of the optical filters and another of the optical filters, and between the other of the optical filters and the planarizing film.

13. The image pickup element according to claim **12**, wherein the protective film includes another protective film formed between the planarizing film and the silicon substrate.

14. An imaging apparatus, comprising:

an image pickup element including

condenser lenses made of a resin containing fine metal particles,

photoelectric conversion elements formed in a silicon substrate and each configured to photoelectrically convert incident light that enters from an outside through a corresponding one of the condenser lenses,

a protective film made of a silicon compound, the protective film being formed between the condenser lenses and the silicon substrate, and

optical filters each formed between a corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough, wherein

the protective film is formed between the condenser lenses and the optical filters; and an image processing unit configured to execute image processes on data items of images captured via the image pickup element.

15. A manufacturing apparatus configured to manufacture an image pickup element, the manufacturing apparatus comprising:

a photoelectric-conversion-element forming unit configured to form, in a silicon substrate, photoelectric conversion elements configured to photoelectrically convert incident light;

a protective film forming unit configured to form a protective film made of a silicon compound on an incident side of the silicon substrate in which the photoelectric conversion elements are formed by the photoelectric-conversion-element forming unit, the incident light entering the incident side of the silicon substrate;

a condenser lens forming unit configured to form condenser lenses each made of a resin containing fine metal particles on a side opposite to the silicon substrate side of the protective film formed by the protective film forming unit, the condenser lens being configured to condense the incident light; and

an optical filter forming unit configured to form optical filters, wherein the optical filters are each formed between a corresponding one of the condenser lenses and the silicon substrate and are each configured to limit a wavelength band of the incident light to be transmitted therethrough, wherein the protective film is formed between the condenser lenses and the optical filter.

16. A manufacturing method for a manufacturing apparatus configured to manufacture an image pickup element, the manufacturing method comprising:

forming, in a silicon substrate, photoelectric conversion elements configured to photoelectrically convert incident light;

forming a protective film made of a silicon compound on an incident side of the silicon substrate in which the photoelectric conversion elements are formed, the incident light entering the incident side of the silicon substrate;

forming condenser lenses each made of a resin containing fine metal particles on a side opposite to the silicon substrate side of the protective film, the condenser lens being configured to condense the incident light; and

forming optical filters each formed between a corresponding one of the condenser lenses and the silicon substrate and each configured to limit a wavelength band of the incident light to be transmitted therethrough, wherein

the protective film is formed between the condenser lenses and the optical filters.

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